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INTRODUCTION TO ZOOLOGY

BY

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MALHOTRA BROTHERS
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Aller Anfang ist schwer
—A German Proverb.

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PREFACE

This book provides a general introduction to zoology. It is primarily intended for the use of freshmen and sophomores in colleges and universities and attempts to cover all aspects of the subject. It comprises a general account of the properties of life, animal biology and a survey of the Animal Kingdom, followed by general principles of biology, as shown by the Table of Contents. It has been found best to begin with the frog, a relatively common, easily handled and large animal, then to turn to the Protozoa and work up the scale to man. Experience has shown that a systematic approach provides a sound and rational understanding of the structure, functions and behaviour of animals. An attempt has however been made to combine the advantages of the "phylum method" with those of the "types method" and the "comparative" or the "principles method" of treatment. The "project method", has not been found to harmonize with the scope of this book. The Synopses of Classification, extending to orders or families, with common or notable examples, are intended for reference. The classification followed in each case is that of the most recent and the best known authority and includes fossil forms also. A Glossary of the more important technical terms is appended at the end. The Bibliography includes a few selected works, in which the student will find both elementary and advanced material for reference and further study. It is hoped that he will not be too rigidly bound down to his textbook and the prescribed syllabus, but will enjoy reading a wide variety of works. The omission of a list of "test questions" from the book is deliberate; its inclusion is incompatible with the aims of this book.

While I have kept in view the recent advances in various fields in the subject, I have not however attempted to make the book so up-to-the-minute that it contains a mass of premature conclusions from very recent works. Though the recent progress in biological sciences has proved fatal to it, the classical cell theory, for example, is discussed in its original form. This has been found necessary because a rational understanding of the subcellular phenomenon is impossible without a knowledge of the classical theory. In keeping with modern trends however, I have laid greater emphasis on the ecological aspect than has hitherto been the case.

A book of this kind naturally involves great condensation in order to keep within reasonable limits. Although the book does not claim to be a

record of new discoveries, it is not at the same time wholly a compilation, since it is largely based on my own observations. Most of the types of animals described have been dissected dozens of times in the course of class demonstrations or on other occasions. A large number of statement of facts has been verified by personal observations.

The book is profusely illustrated. Most of the figures are original and were prepared specially for this book from specimens in the Zoology Museum, St. John's College, Agra, under my supervision by Mr. Rangi Lal Jain, Part-time Artist, Entomology School of Research, Zoology Department, St. John's College. A certain lack of uniformity of quality in some of the figures that may be visible to a discerning eye is due to the fact that the artist had actually to be trained as the work progressed. Some of the figures have been redrawn or borrowed from other publications, the sources of which are suitably acknowledged in the legends. A few figures that are from my own pen are recognized by my initials. All the photographs reproduced as three-colour phototints and half-tones were taken by me.

In the preparation of this book I have received considerable assistance from a large number of my past and present students. I am particularly indebted to Dr S. P. Bhatnagar, Messrs V. P. George, Ravi Prakash Mathur, Omesh Narain Saxena, Visva Nath Sinha and S. S. Khanna for dissections and for preparations of skeletons and microscope slides. Mr. S. N. Rao, Research Assistant, gladly undertook the "drudgery" of typing the manuscript for the press. He and my other Research Assistants Dr (Miss) A. Philip and Mr. Chandy Kurian, helped me in reading through the printer's proof sheets. To Mr. D. S. Chowdhery, Lecturer in Anatomy, Thomson Medical College, Agra, I owe a deep debt of gratitude for several human bones, embryos and some of the histological slides figured in the book. My wife and my son Visvanath collected a number of specimens, especially the molluscan shells, some of which illustrate the following pages. I must also thank Mr. C. Mahajan, Principal, St. John's College, Agra and my predecessor in office Dr L. P. Mathur, for facilities and for numerous other courtesies. Last but not the least, my thanks are also due to the Publisher and the Printer for the pains they have taken in bringing this book out.

The aim that underlies this book is twofold: firstly the study of the structure of animals, correlated with their functions, leading to the knowledge of human physiology and the relation of man to other animals and secondly the study of evolution and all that it involves. It is hoped that this book will not merely help the student in preparing for various

examinations but also arouse in him an abiding interest in the subject and create a love for animals. I have merely stated my intentions but cannot say whether I have succeeded in writing a book that will achieve all these. I have no doubt committed many mistakes and a few misprints have also crept in. It is fashionable for an author to crave for the readers' indulgence for these mistakes. Perhaps such mistakes are inevitable and may be excusable in themselves, but it is inexcusable not to use every effort and resource to prevent, discover and correct them. I therefore seek criticism from all, students and teachers alike, who will use this book, rather than indulgence for my shortcomings.

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St. John's College,
AGRA, March 2, 1950.

M. S. MANI

CONTENTS

PAGE

CHAPTER XI

CHAPTER XII

CHAPTER XIII

CHAPTER XIV

CHAPTER XV

PAGE

CHAPTER XXVI

INTRODUCTION

DEFINITION AND SCOPE

ZOOLOGY (from the Greek *zoön*, allied to Sanskrit *jeevan*=animal and *logos*=discourse) is the science of animals. It is one of the two great subdivisions of BIOLOGY or the science of life. The other subdivision of biology is BOTANY or the science of plants. Biology, geology, chemistry, physics and astronomy constitute the various branches of Natural History.

The aim of zoology is an understanding of the structure and bodily functions of animals, their distribution, habits, behaviour, relationship to one another and to the surroundings in which they live, their classification, development, origin, past history and economic importance.

The subject matter of zoology includes all the animals living on the earth at present and the animals which lived in the past. Animals are found everywhere on the earth : in water, on land and in the air. They are found even within our own bodies. Many are found underground, in the hot dry deserts, in hot and sulphur springs, on high mountains and in deep wells. There is in fact not a square inch of the earth's surface which is not inhabited by some kind of animal or other. The number of individuals of animals on the earth is beyond computation. It is however possible to make an estimate of the kinds of animals. Over a million different kinds or ***species*** of animals, living at the present time, have so far been named and described by zoologists. Every year hundreds of new animals are discovered. Millions of totally different kinds of animals lived in the distant past and perished without leaving behind any living representatives. Indeed we only know of their past existence from their petrified bones, which are found buried as ***fossils*** in rocks. The great giant ***dinosaurs*** (Fig. 1), some of which attained a length of over 150 feet and weighed several hundred tons, are examples of such ***extinct*** animals.

Zoology tells us that animals first appeared on the earth nearly a thousand million year ago. They all at first lived in the sea and were mostly minute and very simple in oraganization. They did not possess complicated organs like mouth, stomach, brain, etc. After a long time, they gradually became more and more complex and developed various organs for performing different functions. Many of them ultimately left the sea in search of food or to escape from enemies, and gradually

occupied the land or even invaded the air. Man, who is also an animal, came last of all, hardly a million year ago.

FIG. 1. *Brontosaurus*, the "thunder reptile" (so named from the tremendous noise it is supposed to have made while walking), is a giant dinosaur that flourished over one hundred million years ago. It is now extinct. It measured at least 60 ft. long, had a bulky body but a minute head. Note the size of puny man drawn to scale for comparison. Zoology speaks not only of living animals of the present but also of the extinct ones of the past. (*Redrawn from an original photograph of a reconstruction in the Zoology Museum, St. John's College, Agra.*)

The subject matter of zoology is thus so vast and so varied: it speaks of the fish in the sea, the beasts of the forest, the birds and insects of the air, and of the great dinosaurs and other numerous extinct animals. It also speaks of man himself. It tells us of the structure of our body and describes our past history and heritage. It forms the basis for agriculture and for medicine. It has many branches:

Morphology deals with the structure of animals

Physiology describes their bodily functions

Embryology describes the development of an animal
Heredity is the study of inheritance of animals
Taxonomy is the classification of animals
Palaeozoology speaks of the fossil remains of extinct animals
Ecology describes the relation of animals to their surroundings
Zoogeography deals with the laws governing the distribution of animals in different parts of the earth
Pathology deals with abnormalities in animals
Psychology describes the mental phenomena of animals and
Evolution describes the origin and differentiation of animals.

The following subdivisions of zoology are restricted to the special study of a particular group of animals :

Protozoology is the branch which is concerned with the minute unicellular organisms or *Protozoa*
Entomology is the study of insects
Ichthyology is the study of fishes
Ornithology is the study of birds and
Anthropology is the study of man and his culture.

In addition, a list of practical applications of zoology includes *animal husbandry* (breeding of domestic animals), *poultry* (fowl-rearing),

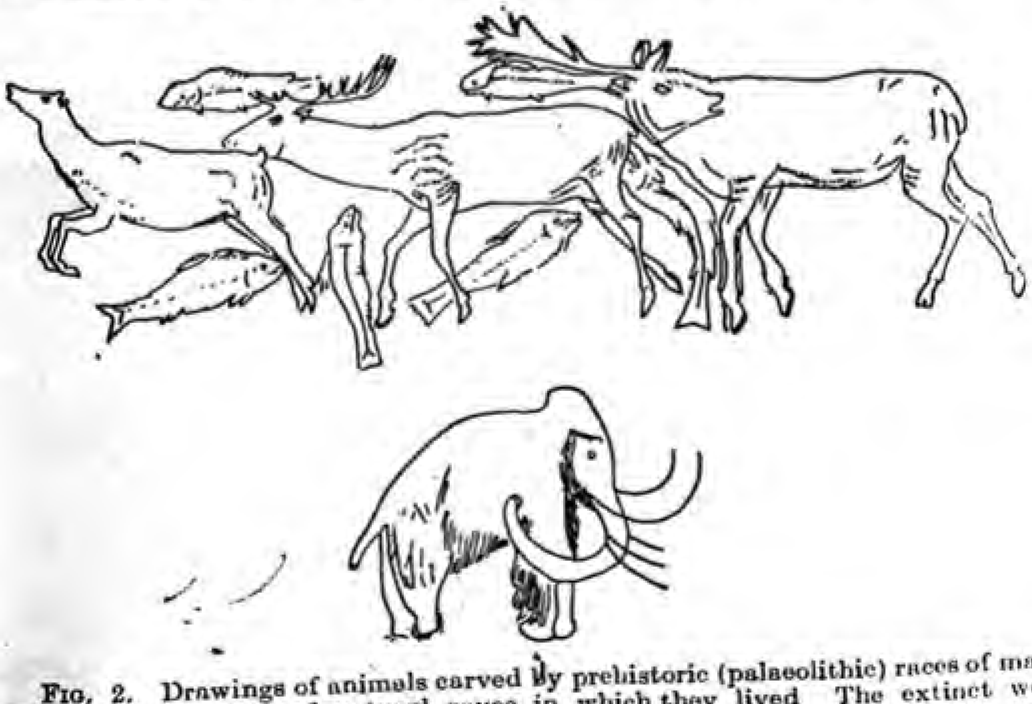

FIG. 2. Drawings of animals carved by prehistoric (palaeolithic) races of man on ivory and on the walls of natural caves in which they lived The extinct woolly mammoth, reindeer and fishes, with which the first men were familiar, are represented here. (*Adapted from various sources*).

apiculture (bee-keeping), *medicine* or the art of curing diseases and *hygiene*, which teaches us the principles of maintaining health.

Zoology is perhaps as old as man himself. Prehistoric races of men, who lived a quarter of a million year ago, were keen observers of animals. They have, for example. left down to us records of their vivid impressions of the animals with which they were familar. They carved on bones crude but wonderfully accurate figures of the woolly mammoth, reindeer, etc., (Fig. 2). As a pure science, zoology may be said to have been founded by the Greek philosopher ARISTOTLE (384-320 B.C.). As aniplaped science,zoology was already much advanced in India long before the Greeks. The great Indian epics RAMAYANA and MAHABHARATA contain references to *Asvashastra* (the science of horse) and *Gajashastra* (the science of elephant). The Chinese knew the use of silk, which is produced by the silkmoth caterpillar, several centuries before the Greeks.

CHAPTER I

LIFE

THE LIVING AND THE NON-LIVING

The world around us comprises two more or less distinct classes of substances—the ***living*** and the ***non-living***. Animals and plants are living ***organisms*** but sand, rock, metals, etc., are non-living matter. In the majority of cases, living or ***organic*** matter can easily be distinguished from the non-living or ***inorganic matter***. Even an uneducated person, for example, can tell the difference between a dog and a stone ; the dog is alive and the stone is dead.

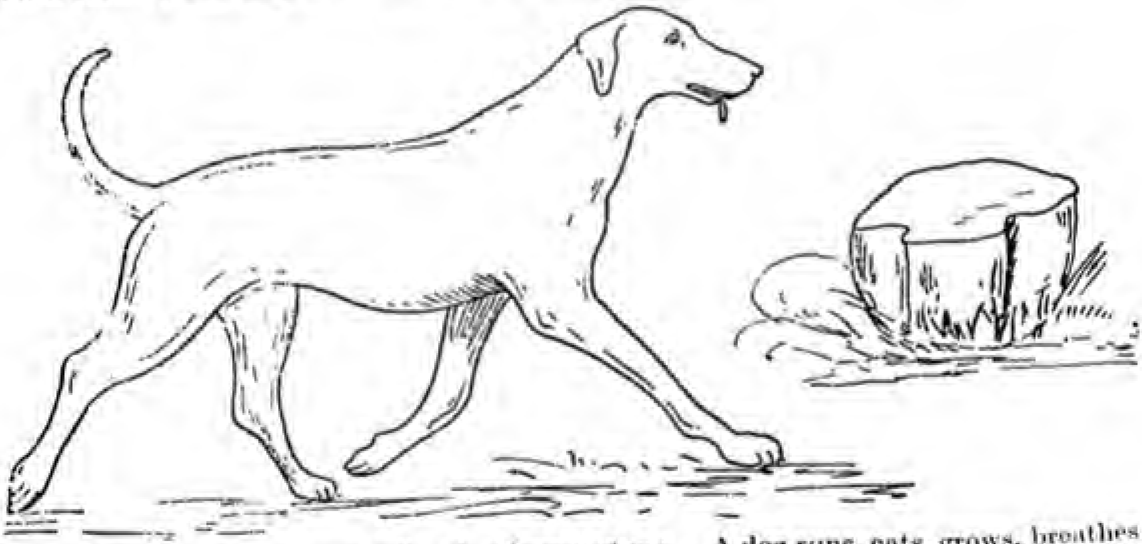

FIG 3 Any one can tell a dog from a stone. A dog runs, eats, grows, breathes and gives birth to puppies—it is a living organism. A stone never eats, breathes, grows and never gives birth to stones ; it stays where it is put—it is lifeless matter.

A dog runs, takes food and grows, it can bark or bite and can give birth to puppies. A stone cannot do any of these things, because it is not a living thing (Fig. 3). Seeds of plants and "resting stages" of many lowly animals appear wholly inert and lifeless but if these are given favourable conditions, show signs of life. Ordinarily living matter may be recognized by several unique characteristic features, *viz.* 1. autonomous movements, 2. characteristic form and size, 3. definite organization, 4. characteristic chemical composition, 5. metabolism, 6. irritability, and 7. reproduction.

Autonomous movements.—Living organisms generally exhibit various kinds of movements. An animal, so long as it is alive, can move from place to place. It can chew food. It can kick its legs or wag its tail. Fishes swim, birds, bat, and insects fly. Lifeless matter like a piece of stone cannot move of its own. It remains where it is put.

Many non-living things, like a locomotive steam engine or a motor car, can also move. Their movements are, however, quite distinct from those of a cow for example. An engine or a motor is a man-made machine and it can only move if worked by a living being. It cannot move spontaneously. Living organisms on the other hand move spontaneously, *i.e.*, their movements are *autonomous* and do not come from outside. Autonomous movement is perhaps the most striking of all the unique characters of living matter. It is therefore the first test of life. Primitive men and animals indeed always associate movement with life. Carnivorous animals instinctively grab at any moving object, mistaking it for their prey. If, for example, you wave a small piece of ribbon or other similar object in front of a frog, it will snap at the ribbon thinking it to be a fly.

Form and size.—All living organisms usually have a definite form and size, constant within certain limits for the same kind of animal or plant. All cats, for example, have a definite average size and an unmistakable form. Non-living matter varies very much both in form and size. A crystal of copper sulphate may be of the size of small sand grain or may be as large as a football. Water or air have no definite shape of their own or size. The constancy of form and size is one of the unique characters of living matter.

Organization.—Living matter has a definite organization in all cases. It is built of various structures and organs performing various functions. All parts of living organisms are composed of microscopic units called ***cells***. Some plants and animals are single cells, while others like man, contain several billion cells in their body. Aggregates of similar cells performing the same function constitute a ***tissue,*** as for example, muscle nerve, bone, etc. Many tissues go to make an ***organ***. In non-living matter any organization depends entirely on the constituents and their mode of formation. Most living beings have ***individuality,*** *i.e.*, a living organism is an entity; it is a discrete unit. Though we can have half a brick or quarter of a crystal of common salt, we cannot have half a horse or three-fourths of a cow. Whether minute or large, all living organisms are complete indivisible units and possess all the characteristic properties of life.

Chemical composition.—The body of all living organisms is largely made up of carbon, oxygen, hydrogen, nitrogen and varying amounts of sulphur, phosphorus, calcium, sodium, iron, chlorine, etc. These elements are combined together into a highly complex mixture of elements and compounds. This mixture of living substance is called ***protoplasm***. Protoplasm is never met with anywhere except in a living organism ; it is in fact *living matter*. It has been called the *physical basis of life*.

It was first discovered to be a distinct substance in 1835 by a Frenchman, DUJARDINE by name, who called it ***sarcode***. The name protoplasm was given by a German, HUGO VON MOHL, who described it in plants for the first time in 1846.

Protoplasm differs in different animals. In the same animal the protoplasm in muscle is different from that in a nerve. Inspite of these differences, all protoplasms have many common characteristic properties. These properties are really the properties of living matter.

Protoplasm can be recognized by its physical character, microscopical structure, chemical composition and physiological character.

PHYSICAL CHARACTER OF PROTOPLASM : Protoplasm is a viscid, gelatinous, jelly-like, colourless, translucent colloidal emulsion. In a colloidal system, ultramicroscopic particles or droplets are suspended in a liquid. The suspended substance is called *dispersed medium* or *discontinuous phase* and the liquid in which it is dispersed is called the *dispersion medium* or *continuous phase*. The size of the colloidal particle is about 0.000,0001 mm. In a true solution the dispersed particle is the molecule. A colloidal emulsion results if droplets of one liquid are suspended in another. In protoplasm, water is the continuous phase, in which ultra-microscopic solid particles are in colloidal suspension or droplets of liquids are in emulsion. In addition to these particles and droplets, protoplasm also contains larger microscopic particles, crystals, fat droplets, etc., in simple mechanical suspension. A large number of mineral salts are also dissolved in water and other liquids in the protoplasm.

MICROSCOPICAL STRUCTURE : Under the microscope protoplasm appears like a heavy viscous liquid with innumerable granules of different sizes. Sometimes numerous fibres form a close network, giving the protoplasm a *reticular* appearance. Very often large droplets are distributed in the liquids, so that the protoplasm has an *alveolar* or foam-like appearance (Fig. 4).

CHEMICAL CHARACTER : The exact composition of protoplasm is not known. It does not however contain any new element, which is not already known in the non-living world. The following elements are found in protoplasm :

Carbon about 20%
Oxygen 70%
Hydrogen 10%
Nitrogen 30%

Sulphur, phosphorus, iron, magnesium, calcium, sodium and chlorine constitute less than 1% of protoplasm. Although these elements occur in such minute proportions, they are of vital importance. Some of these substances are specially abundant in certain forms of protoplasm, for example, iron in the protoplasm of blood and phosphorus in the protoplasm of nerve. Without these minute quantities of iron or phosphorus there can be no blood or brain.

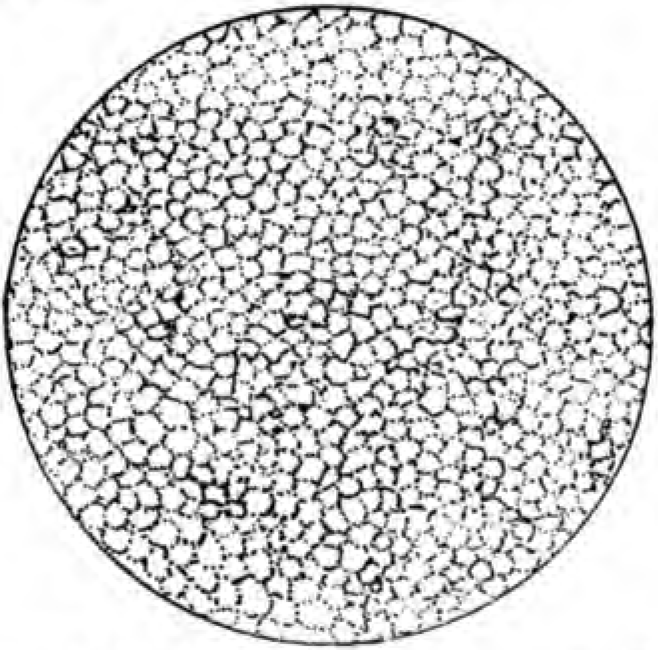

FIG. 4. Appearance of protoplasm under the microscope. When highly magnified, protoplasm looks like a "foam".

The following chemical compounds are also found in protoplasm: Proteins, fats, carbohydrates, water, salts and gases.

Proteins are complex compounds of carbon, oxygen, hydrogen, nitrogen, sulphur and sometimes phosphorus also. They are giant molecules, some of them being nearly as big or bigger than colloidal particles. Proteins are indeed colloidal in nature. They have high molecular weights, often as high as 500,000 and are built of units known to the chemist as ***amino acids***. Most of them do not dissolve in water but they are capable of absorbing considerable quantities of it and swelling up. Their molecules are too big to allow them to pass through the pores of a filter. They are however invisible under the highest power of the microscope. Their complex chemical make-up and their large size enable them to

react with a very large number of other substances. The number of proteins found in different protoplasms is very great. They are in fact the bricks of which protoplasm is built up. They perform a variety of functions in protoplasm : some aid in liberation of energy, others store up energy, still others form protective envelops.

Fats and ***carbohydrates*** are also complex compounds of nearly the same elements but in very different proportions and with different arrangement of atoms. In protoplasm they serve as fuel for liberation of energy. In addition to these compounds, there are also many ***enzymes***. Enzymes are considered to be proteins but unlike the ordinary proteins, they act as *catalytic* agents. ***Vitamins***, which are chemical compounds having NH_2-radicals, also occur in protoplasm.

Water is the most abundant constituent of protoplasm, of which it forms nearly 96% by weight. It is found both in the free state and in chemical combination. It is capable of dissolving a larger number of substances than any other liquid and it thus makes possible many chemical reactions in protoplasm. Among the salts commonly found in protoplasm are sodium chloride and calcium carbonate.

In protoplasm, these elements and compounds are chemically aggregated together or exist in complex mixtures. Protoplasm therefore is not a simple substance but is a heterogenous mixture of solids in liquids, liquids in liquids and liquids in solids. Surrounding these solid and liquid regions there are molecular ***surface films***. A surface film has the property of *absorbing* the molecules of many substances. Many of the chemical activities of protoplasm are really due to its colloidal nature and to its surface films. It is chemically extremely *unstable* and highly variable. It is always undergoing chemical decomposition and some of the complex molecules are always constantly breaking down into simpler substances. At the same time new material is constantly being built up into complex compounds.

PHYSIOLOGICAL CHARACTER : Living matter is continually breaking down and as continually rebuilding itself up. The sum-total of these vital activities of ***maintenance, automatic repair*** and ***growth*** is called ***metabolism***. Metabolism is the unique character of living matter alone. The building-up activity is called ***anabolism*** and the breaking down is called ***catabolism***. Anabolism and catabolism are thus two phases of metabolism. Building-up and growth require material and energy : these come from the food. Energy is liberated from the oxidation of the food by the oxygen of air breathed in by the organism. When

the building-up process outweighs the breaking-down process, the organism *grows*. Lifeless things, for example crystals, also grow but their growth is due to the addition of matter on the outside and no transformation of material takes place. Living organisms grow by transforming the non-living material into the living material within themselves.

As explained above, the breaking-down process is automatically balanced by the building-up process. Living matter has thus the power of *automatic repair*. If, for example, a boy and his bicycle get smashed up in a common accident, the injuries to the boy will automatically heal up in time but the damage to the cycle will not.

If the process of breaking-down exceeds that of building-up, the living matter undergoes ***decay*** and finally ***death*** supervenes. Living matter is therefore continually dying but as continually creating itself.

Irritability and adaptation.—Living beings have the inherent power to receive and respond to external stimulus ; they react to changes in the environment. The changes in the environment act as ***stimuli***, which produce in the organism the ***response***. This power of responding to stimuli is called ***irritability***.

If you drive a nail in a stone or wood, it does not cry or move away, but a pin-prick in your finger will make you draw your hand away. You may also cry because of the pain! Your response is spontaneous or automatic. Similarly an electric shock makes the muscles of an animal, so long as it is living, contract. Some stimuli like abundant oxygen, light, alcohol, etc., make the response vigorous, others like poisons, carbon dioxide, etc., depress the responsive activities of living beings. Because the conditions of heat, cold, light, pressure, moisture, food, oxygen, etc., in the surroundings of an organism are continually changing, the latter also continually responds to each new change. Some of these responses are useful to the organism, which thus becomes adjusted or ***adapted*** to the changed conditions. If the water of a pond dries up, all the aquatic animals in it either migrate away or bury themselves under the mud to "sleep away" the summer. Non-living matter does not respond or adapt itself in this way.

Reproduction.—The capacity to reproduce themselves is a very important feature of living beings. Each organism has the ability to duplicate itself, *i.e.*, of producing a fresh version of itself and thus giving rise to numerical increase. A mango tree produces the seeds, which grow into mango trees again. A dog gives birth to puppies, which grow up into dogs and in their turn give birth again to puppies. Lifeless matter does not re produce itself ; a pencil does not for example give rise to another pencil.

There is thus a regular *rhythm* in the activities of living matter. It undergoes a regular cycle of changes : birth, growth, reproduction, decay and death. Such an orderly cycle of changes is not characteristic of lifeless matter.

Because they liberate energy by oxidation of the living substances, living organisms have often been compared to a fire. The famous French chemist LAVOISIER considered life as a sort of *slow combustion*. A fire is merely rapid combustion but with the same results as in the case of the slow combustion in the living body. In both the cases matter is converted to simpler forms and energy is liberated. In both fire and life carbon dioxide and water are produced as waste products of the combustion. The difference between the two is only of speed. We might indeed consider the human body as slowly burning itself away !

The body of an animal has also frequently been compared to a machine or a huge and complicated factory. The resemblance is however very superficial. An animal body is far more complicated than any of the most complicated man-made machines. A machine is controlled from outside ; the body of an animal controls itself from inside. A machine cannot also repair itself but in the case of an animal this is constantly going on. Machines cannot reproduce themselves as animals do.

Nature of life.—The distinction between the living and the non-living thus appears to be quite sharp and unmistakable. This is however not really the case. The differences between the two types of matter are not absolute. There are many exceptions. The so-called unique characters of living matter enumerated above are by no means the exclusive properties of life. The ordinarily non-living matter also shares many of these characters of living matter. Autonomous movements are, for example, not always a safe guide in determining whether a certain thing is alive or not. Microscopic particles of dust suspended in water costantly move to and fro, hither and thither. These are the *Brownian movements*, named after a botanist BROWN who first observed them. All matter, living as well as non-living, are composed of *atoms*, of which 97 kinds are so far known. Atoms are inconceivably minute and are themselves built of still smaller *electrons* and *protons*. Each atom resembles a miniature solar system. The electrons are rapidly revolving round the central protons. Some of these outermost electrons of an atom often knock off but the atom becomes whole again automatically by picking up electrons from outside. Thus it shares the power of automatic repair and maintenance of its organization, a feature characteristic of living

matter. It is now known that matter and energy are one; matter creates itself from energy, just as living matter reproduces itself.

There are certain substances known as ***viruses***. Viruses are complex protein molecules of high molecular weight, that exhibit the characteristic properties of living cells. The average size of a virus is 25 millimicra.* It contains about 400 proteid molecules. Some of them are even smaller than certain protein molecules. The smallest bacterium, which is hardly visible under the highest power of the microscope, is nearly ten times larger than a virus. Being much smaller than colloids, many viruses pass through filter pores and are therefore called ***filterable viruses***. A virus can never therefore be seen under an ordinary microscope but they have recently been photographed under the powerful electron microscopes. Many of them produce diseases in animals and plants. Smallpox, influenza, hydrophobia, etc., are some of the diseases caused by viruses. They can be crystallized just like a non-living substance, but they live as parasites in living beings and reproduce exactly like living organisms. They thus combine the properties of the living and the non-living matter. It is possible that a virus is a transition stage between the living and the non-living—on the borderland between life and the lifeless.

The great Indian scientist, late J. C. BOSE, (Fig. 5) showed by many interesting and conclusive experiments that the so-called dead or non-living matter behaves exactly like the living matter in many ways. A metal, for example, can be poisoned or stimulated like a living organism. He showed that what we ordinarily call non-living matter also exhibits irritability just like living matter. This means what we call dead is really alive! There is thus no real distinction between the living and the non-living. The two merge into one continuous series and there is no sharp line of demarcation between them. We cannot absolutely say where life ends and where death begins. The modern conception of life is totally different from what we usually read in text-books.

One can only conclude that there is no such thing as lifeless matter; all matter is alive. Physicists tell us that matter itself is largely energy. Life, matter, energy—these are three names for something, the exact nature of which we do not understand. For ordinary purposes, however, we can define *life as the sum-total of the delicately balanced reactions in protoplasm.*

Origin of life.—If there is thus no precise answer to the question "what is life?" and if there is no absolute and sharp distinction between

* A millimicron is one-thousandth of a micron, and micron is one-thousandth part of a millimetre.

living and non-living matter, our ideas regarding the origin of life can only be mere speculation. Ignoring the many fantastic ideas, there are five important theories regarding the origin of life :

1. Mosaic theory of special creation
2. Abiogenesis or spontaneous generation
3. Meteorite theory
4. Cyanogen theory and
5. Virus theory.

FIG 5. Late J. C. Bose, an Indian scientist, whose researches on irritability have revolutionized our ideas of the living and lifeless matter. He has shown that animals, plants and the so-called non-living matter like metals all exhibit the property of irritability and can be stimulated or poisoned in the same way. The difference in the reaction is only of degree. (*Original photograph of a portrait in St. John's College, Agra*).

The Mosaic theory is of Jewish origin and is expounded in the Book of Genesis in the Old Testament of the Christian Bible. It believes that each animal or plant was separately and specially created in the beginning just as we find at the present time. Two individuals of each kind were produced : a male and a female and these pairs have given rise to all the multitude of individuals of the various kinds of organisms living today. Although it is included in the holy book of the Christians, one need not ascribe any divine origin for the statement and in any case there is no proof of a special creation. All evidence is on the other hand against such a belief

in special creation and immutability of organisms. We have abundant evidence on the contrary that organisms of the past were very different from what they are today. They are always changing, ever becoming better adapted and more and more complex.

The spontaneous generation theory implies that all sorts of animals and plants arise out of dead matter spontaneously, if favourable conditions are present. ARISTOTLE and others believed, for example, that decaying meat gave rise to flies and worms. Toads and frogs were supposed to come from mud. Rats were believed to breed out of old rags and a few handfuls of wheat! Nowadays such ideas are mentioned only to be ridiculed by any intelligent person. In the middle ages the idea of ***abiogenesis*** or spontaneous generation was very strong, until an Italian, REDI by name, showed in 1680 by simple and conclusive experiments that flies do not arise from the meat but from the eggs of other flies which have been deposited on the exposed putrid meat. He showed that flies come from eggs of pre-existing flies and these from the eggs of still pre-existing ones and so on. That is to say, *life begets life*. All life on the earth now has come from pre-existing life: ***omne vivum e vivo*** or ***all life from life***. This merely places the difficulty at a distance but does not by any means solve it. It does not really explain how the first life arose.

Physicists like KELVIN and HELMHOLTZ believed that life came to the earth from some other heavenly body by means of meteorites, which fall daily on the earth from the skies. According to them, life has existed in the universe always and is simply passed on from one planet to another at intervals. In the space between the planets there are pieces of matter called *meteors*, which weigh from a few milligram to several tons. They are mostly composed of iron or nickel-iron. They rush with such tremendous velocity that when they reach our atmosphere the friction with the air causes them to be burnt out completely; they glow and then we have the so-called *shooting stars*. Rarely some of the larger pieces fall on the ground and are often held in awe by superstitious people. The sacred stone at Mecca and the well-known *akash lingh* of the Hindus are examples of such large meteors. It is impossible for any form of life, as we know, to exist on such a meteor, because of the unbelievable cold (equal to $-273^\circ C$) of the interplanetary space in which it occurs and because of the absence of oxygen. Further, this theory also simply shifts the burden of explaining the origin of life to outside the earth but leaves the question how life arose on the meteors unanswered.

There was certainly a time when our earth was in a molten condition and in long course of time cooled down to a solid. PFLÜGER believed that when

the earth was thus cooling, carbon and nitrogen combined to form cyanogen gas. Then water was formed and this combined with the cyanogen and gave rise to hydrocyanic acid. He thought that this acid produced proteins with sulphur. This is plausible but so far no chemist has ever succeeded in bringing about this synthesis in the laboratory.

The virus theory maintains that when matter becomes complex by forming high molecular weight proteins, it begins to exhibit the properties of life. A virus is thus believed to be non-living matter in the process of becoming living matter. This theory is really a modern and a modified version of the older ideas of spontaneous generation. The only difference between the older and the modern theories of abiogenesis is that in olden times, higher forms of life like flies, worms, rats, etc., were supposed to arise from non-living matter. In modern times it is however believed that only very simple forms like a virus arise spontaneously from the non-living and these viruses *evolve* into the other forms of life.

Life had possibly no beginning and no end ; that is, there is no origin or creation of life or matter ; they have always been there and will always be there.

ANIMALS VERSUS PLANTS

The living organisms known to us can be broadly grouped under two great classes, viz. ***animals*** and ***plants***. In addition to all the familiar trees, shrubs, grasses, ferns and mosses, such forms like lichen, fungi and bacteria are examples of plants. Worms, insects, birds, etc., are some of the more common examples of animals. Inspite of the apparent differences between a plant and an animal, they are both living organisms and thus agree in all essential characters.

Similarities between plants and animals.—Both animals and plants are composed of protoplasm and the protoplasm of the two is indistinguishable one from the other. Both are organized in the same way : their bodies are built up of cells, tissues, etc. The metabolic activities of nutrition, growth, automatic repair, wear and tear, reproduction, etc., are common to both. Animals and plants equally require oxygen for respiration and set free carbon dioxide as an excretory product. Both of them have sexes. Plants and animals obey the same laws of inheritance. Like animals, plants are also irritable : they are also capable of responding to external stimuli. BOSE demonstrated that plants also suffer from the effects of pain, fatigue, toxic action of poison, etc., in exactly the same way as animals. As in animals, so also in plants, the sensations of heat, cold, light or of electric shock travel up and down the tissues. These transmissions can be

accelerated or retarded and even inhibited by various agents in much the same way in both animals and plants. The responses of the plants to various kinds of external stimuli are identical with those met with in animals. The only difference between the two is of degree and not of kind : in plants the responses are less intense. Both are equally capable of adjusting and adapting themselves to changing environment.

Differences between animals and plants.—While animals have the power of locomotion, most plants are rooted to the ground and lead a

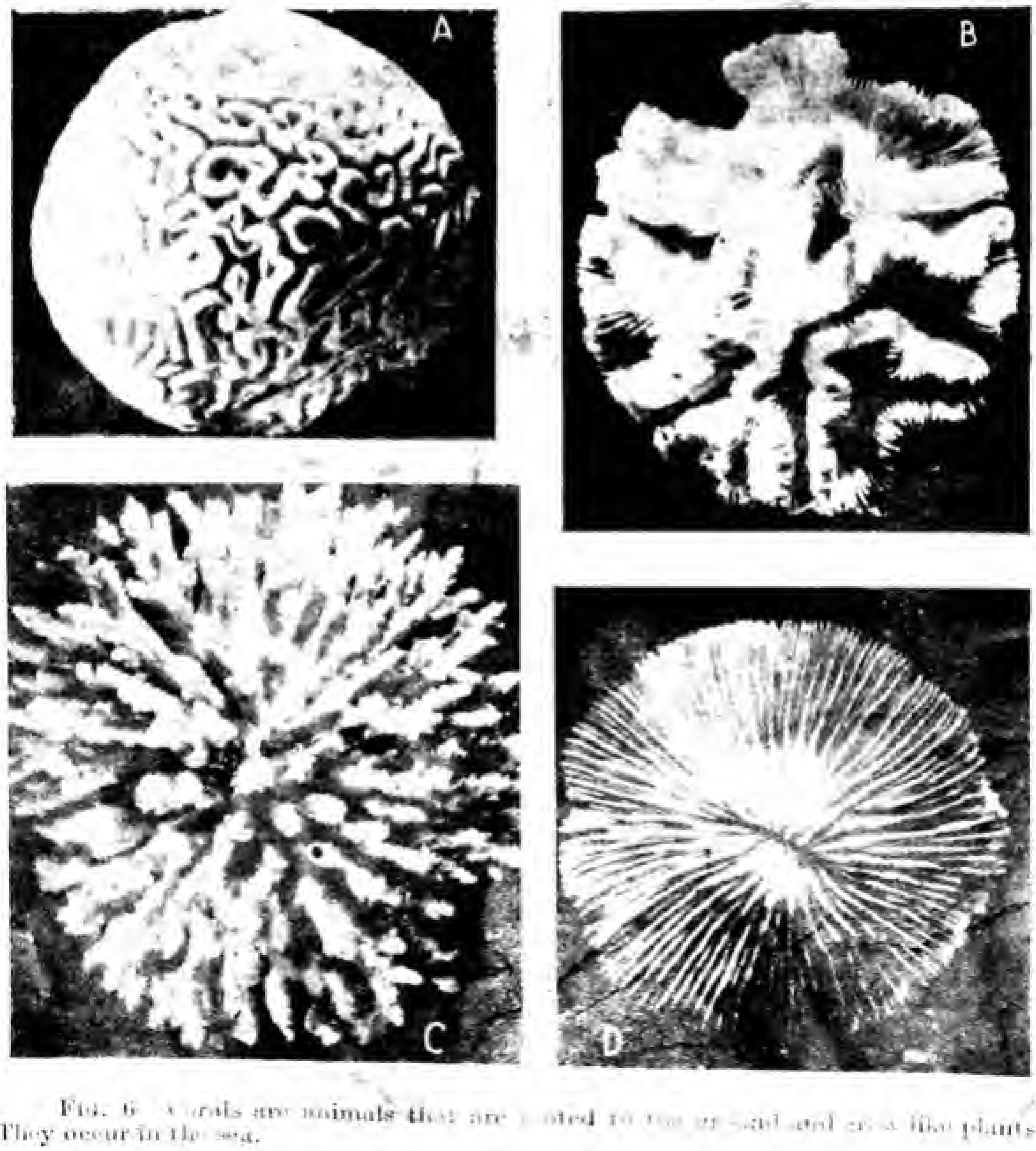

FIG. 6.—Corals are animals that are rooted to the ground and grow like plants. They occur in the sea.

sedentary life. They cannot move from place to place. The sedentary mode of life of a plant is one of the most conspicuous differences between

plants and animals. Numerous exceptions are however known. Several animals like sponges (Fig. 14), corals, (Fig. 6) Bryozoa, barnacles, sea lilies, etc., grow fixed to the substratum like plants and are therefore quite incapable of moving about from one place to another. On the other side there are some plants, for example, the alga *Chlamydomonas*, which can freely move very much like animals.

Apart from this power of locomotion, most animals also exhibit considerable degree of motility. In plants motility is usually inconspicuous.

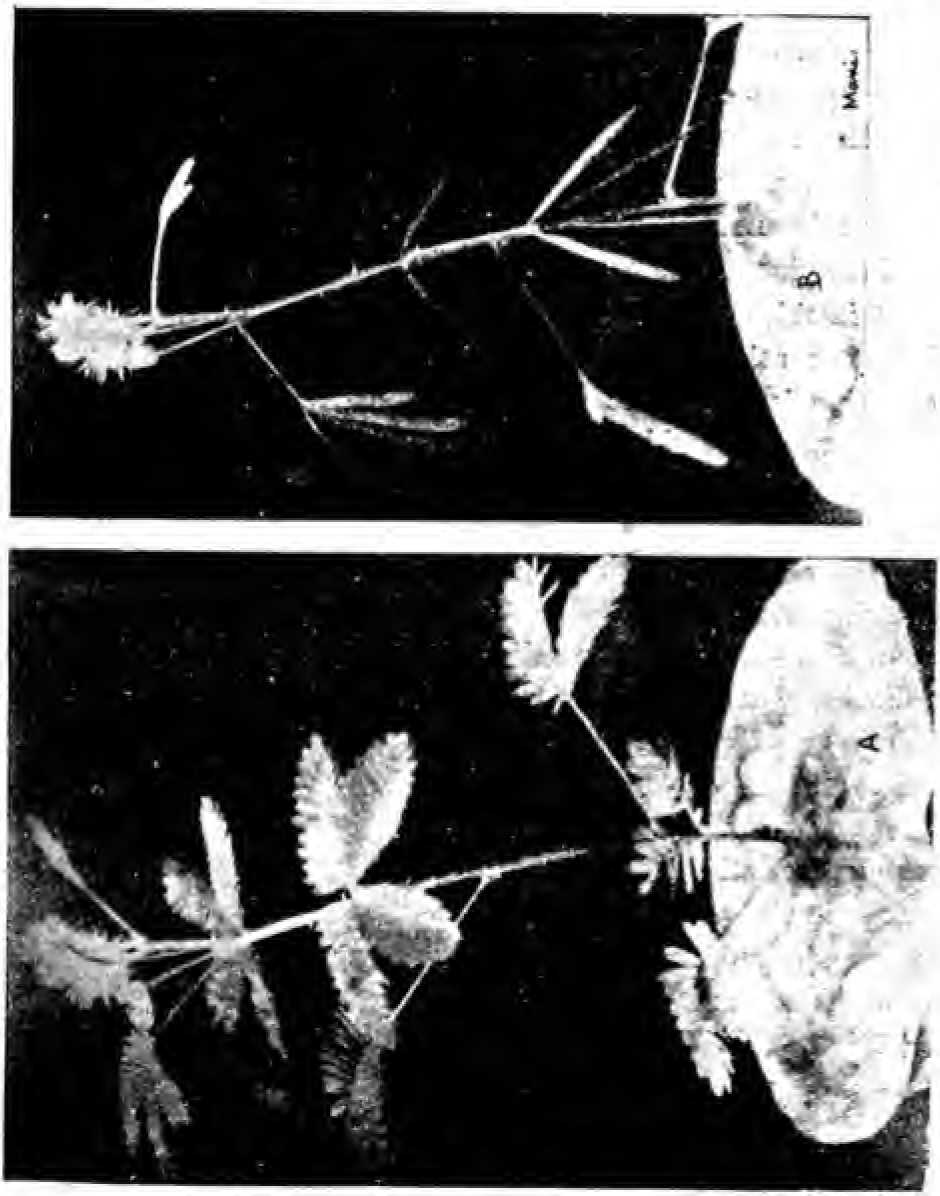

FIG. 7. *Mimosa pudica*, the 'sensitive plant'. A With the leaves expanded. B. The same plant with the leaves folded and 'dropped' in response to being touched. The 'sensitive plant' played a prominent part in the researches of J. C. Bose.

In the case of certain plants, like the sensitive plant (Fig. 7) or *Mimosa pudica*, a high degree of motility is observed in the sudden closing of the leaves, when touched.

Although growth is a common feature for both plants and animals, there is an essential difference between them. Increase in size in a plant takes place by the multiplication of wood cells underneath the bark. Rings of wood cells are added each year, so that the number of annual rings in a tree tells its age. Increase in length or height is effected by growth of the tips of the branches or of the root. In animals however growth takes place throughout all the tissues and organs and is not confined to certain parts alone. A tree practically never ceases to grow. The famous red-wood trees of California, which are giants among all land organisms, are several centuries old and nearly 400 feet high. Although perhaps the oldest living things on earth, they still continue their growth. Animals do not grow at all after attaining a certain characteristic size and age.

In plants the protoplasm is bounded by a distinct ***cell wall*** of *cellulose*. This substance gives rigidity to the plant and is the cause of the inability of the plant to move. In animals on the other hand protoplasm is not bounded in this way or if there is a cell wall it is usually thin and flexible and allows considerable freedom of movement. Plants are branched and thus expose a large surface to air and sunshine. The body of an animal is usually compact and has a minimum exposure of its surface.

Plants and animals differ very sharply in their modes of nutrition. Green plants actually manufacture their food from simple inorganic salts and elements like carbon, oxygen and hydrogen, with the help of sunlight. This process is called ***photosynthesis***. During the photosynthetic manufacture of food, the water absorbed from the soil by the roots and the carbon dioxide absorbed by the leaves from the atmosphere are split up by the energy of sunlight absorbed by the green colouring matter of plants, viz. the ***chlorophyll***. The products of this decomposition are now rearranged and recombined in a new way to form molecules of the sugar glucose, which is then converted into the insoluble starch. The exact steps in the chemical changes which bring about this synthesis are not clearly understood but the whole series may be roughly represented by the following formula :

$$6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$$

The nitrogen derived from the mineral salts absorbed in solution from the soil, is combined with the carbohydrates into proteins and later fats are manufactured in the plant.

Animals are incapable of synthesizing their food in this manner and are therefore wholly dependent on plants or other animals for their food. Animals have either to eat other animals or to eat plants. If there

were no green plants, all animal life would soon disappear. Green plants have in fact been called the *food factories of the world*, because they manufacture food not only for themselves but for all living beings in the world. The mode of nutrition of an animal is called ***holozoic*** as contradistinct from the plant's mode of nutrition, which is ***holophytic.***

There are some well known exceptions in the nutrition of animals and plants. Lower plants like fungi, bacteria, etc., have no chlorophyll in their body and cannot therefore synthesize carbohydrates with the help of sunlight. Like animals, they depend on other plants for their food. Several green plants, which can carry on the photosynthetic manufacture of food, also often resort to the animal mode of nutrition. These are the well known insectivorous plants, like the common Indian *Drosera* (sundew), *Utricularia* (bladder-wort) and *Nepanthes* (pitcher plant) and the exotic Venus' flytrap

FIG. 8. The American insectivorous plant Venus' fly-trap, that actually catches small insects like flies and digests them.

(Fig. 8.). These plants actually capture flies and other small insects and digest them much in the same way as an animal does. Some animals like *Euglena* (Fig. 14), which is very common in fresh-water in India, possess chlorophyll and have the capacity of manufacturing carbohydrates from carbon dioxide and water.

Because of these differences in their modes of nutrition, plants differ in their structure from animals. Since they can make their own food out of simple material universally present, plants have no necessity to move from one place to another in order to find their food. Food in fact comes to them where they are, instead of their going to it as an animal has usually to do. They have consequently no need for such locomotor organs like legs, wings and fins, or special organs of sense like eye, ear and nose. On the contrary, since animals cannot make their food in the way a plant does, but have to capture their food, which does not of course come to them of its own, they have to move. They have therefore developed various organs of locomotion. Since a branched and a spreading body would definitely be an obstacle in locomotion, animals have compact bodies. Further, in order to be able to see their way about and in order to be able to smell and taste the food for its suitability, animals must have organs of special sense and highly developed nervous system.

Animals take with their food not only the essential and digestible material but also a good deal of non-essential and indigestible matter. These latter are ejected from the gut of an animal through the anus by means of ***defaecation***. Plants never eject any faeces.

Lower forms of both plants and animals are almost indistinguishable from one another, because they combine the characters of both. *Chlamydomonas*, *Mycetozoa* and *Euglena* are, for example, considered as animals by zoologists and as plants by botanists! The reason for this intergrading of plants into animals is that both plants and animals have descended from an ancient common ancestor, which very probably resembled these lowly organisms of today. The first life on the earth was thus neither a plant nor an animal but a plant-animal or *Protista*, a hypothetical ancestor of plants and animals.

INTERDEPENDENCE OF ANIMALS AND PLANTS

Animals cannot exist without plants. Animals are dependent on plants either directly or indirectly for their food. Insects, sheep, goat, cattle and other herbivorous animals directly feed on plants. Carnivorous animals like lion, tiger and cat, which naturally feed on the flesh of other animals, are no less dependent on plants, because their food consists mainly of the herbivorous animals. Their dependence on plants though indirect is absolute, for if grass cannot be had, cattle cannot live and the carnivorous beasts will have no food. Ultimately therefore the food of all animals comes from plants either directly or indirectly. Man himself is indebted to the plant for his food.

On the other side of the picture, we find that plants are also dependent in many ways on animals. Animals produce carbon dioxide during respiration. This carbon dioxide is absorbed by the plants for purposes of photosynthesis and is split up into its constituents, the carbon is utilized in the manufacture of carbohydrates but the oxygen is liberated into the atmosphere for use again in the respiration of animals.

Animals and plants thus form links in one continuous and endless food chain. In this food chain the circulation of carbon is an important phase. Carbon, as you have already read, is an essential constituent of protoplasm. Since however the supply of this element on the earth is limited, there must be some means of circulation of carbon, so that the carbon used by one organism may be recovered and made available for an-

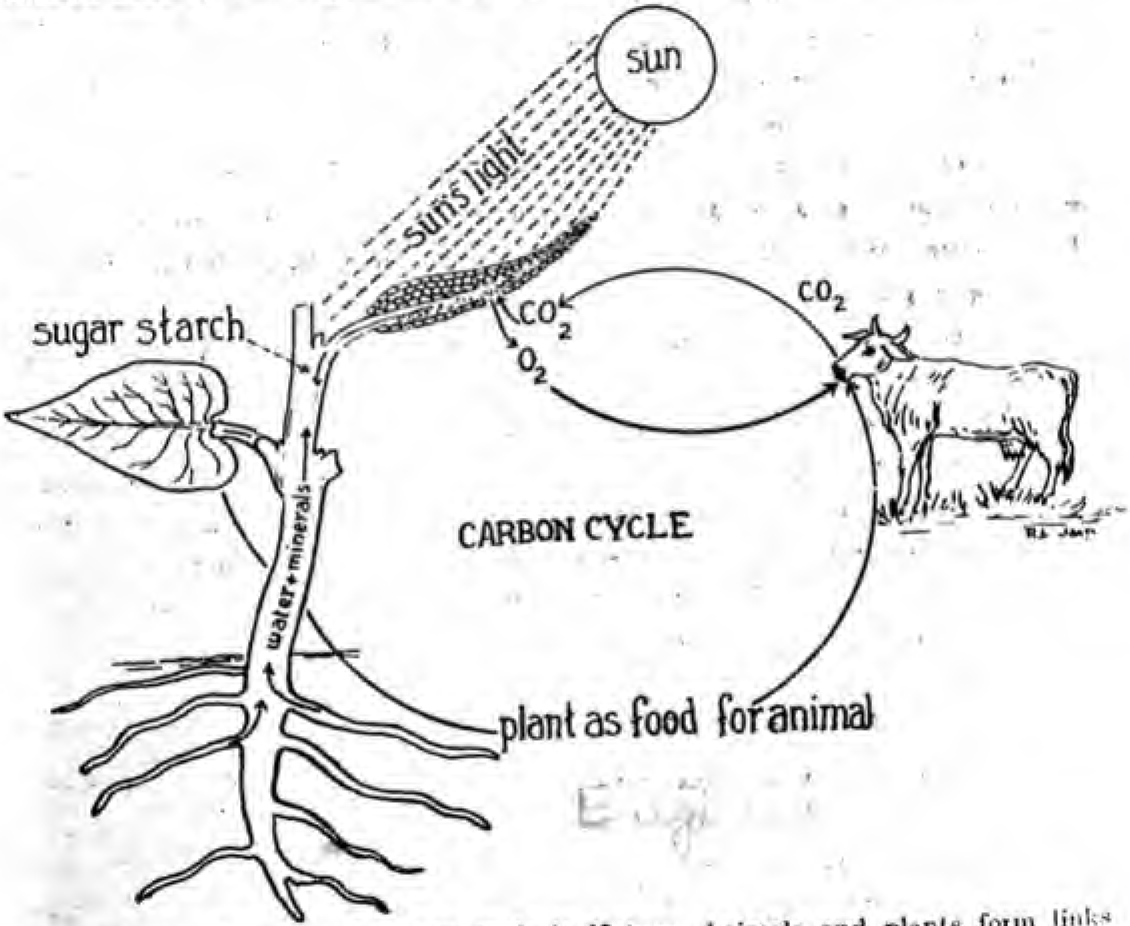

FIG. 9. Diagram of carbon cycle in Nature. Animals and plants form links in the complicated chain of life. They are mutually interdependent. Carbon that forms an essential constituent of living matter, circulates from animal to plant and from plant to animal. This circulation is called carbon cycle.

other organism. This circulation of carbon in Nature is effected by the animal-plant-food-chain and is called the ***carbon cycle*** (Fig. 9).

Animals and plants are also intimately linked together in another way, viz. the ***nitrogen cycle*** (Fig. 10). You already know that nitrogen is an essential constituent of proteins, which form the bricks that make protoplasm. Now nearly four-fifths of the atmosphere comprise nitrogen but most green plants cannot directly utilize this abundant supply. They are generally dependent upon animals for this element.

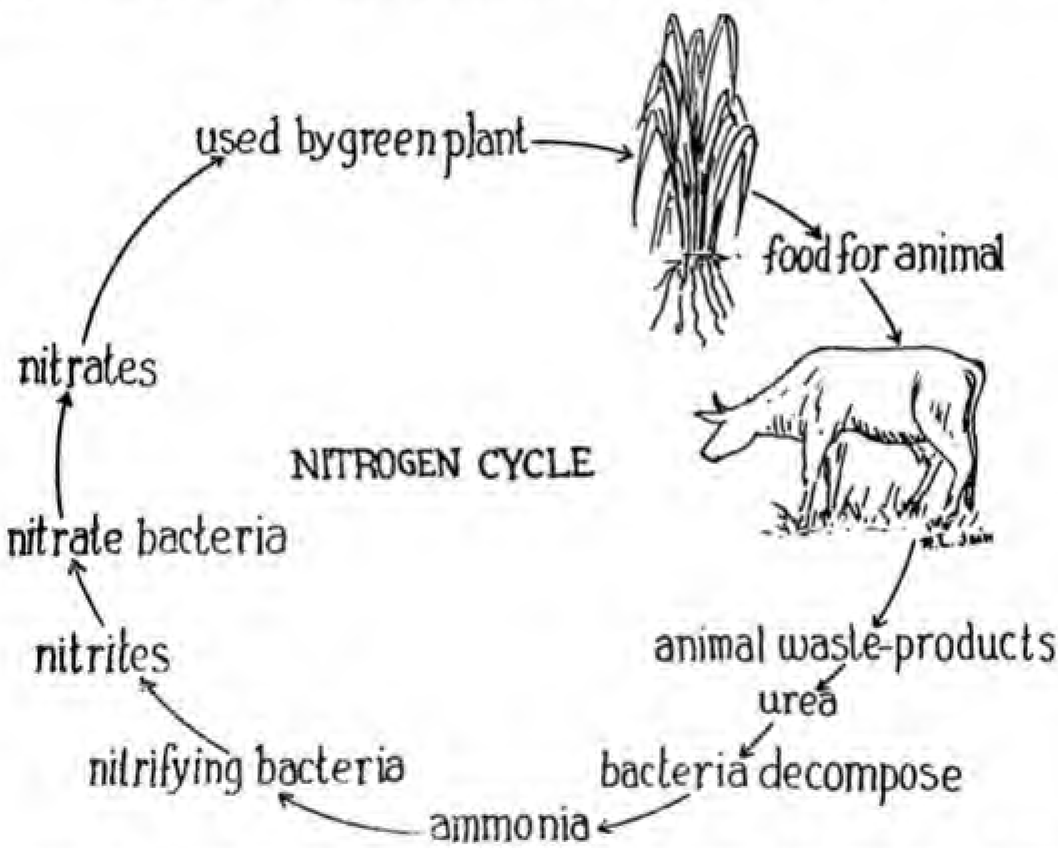

Fig. 10. Diagram of the nitrogen cycle in Nature. Nitrogen that is another essential constituent of protoplasm, circulates from animal to plant and from plant to animal. Some of the important stages in the complicated exchange are shown here.

In addition to the excretory products carbon dioxide and water, the nitrogenous waste material ***urea*** is also formed during metabolism in the body of an animal. Outside the body of the animal, the urea is converted into ammonia by bacteria. Further when an animal dies, its body is decomposed by the activity of various bacteria and all the proteids are ultimately broken down to ammonia. Other bacteria now oxidise the ammonia into nitrites, which are further converted into nitrates by another different set of bacteria. The nitrates, absorbed in dilute solutions from the soil by the roots of plants, form the source of nitrogen for manufacturing proteins once more in the plant.

Animals and plants are naturally intertwined in several other ways also. For example, many flowering plants depend on bees, butterflies,

(*See* Frontispiece) moths and some birds for cross-pollination of their flowers. The dispersal of seeds and fruits of many plants is also effected by animals. The animal *Hydra*, (Fig. 15) which is abundant in any fresh-water pond, often contains within its body many minute green plants called algae. The algae obtain their carbon dioxide and nitrogen from *Hydra*, while the latter gets a share in the products of the photosynthetic activity of the algae.

RESUMÉ

1. Although a sharp line of distinction between the living and the non-living is impossible on the borderland between the two kinds of matter, ordinary forms of living beings can be readily distinguished from the lifeless matter by certain unique characters, like autonomous movements, organization, metabolism, irritability and reproduction.

2. Any precise definition of life is impossible. We do not also know how life arose first. Probably life, matter and energy are merely different names or phases of some ununderstood entity.

3. Plants and animals agree in all essentials of life. The chief difference between the two lies in their modes of nutrition: viz. the holozoic and holophytic nutritions. Although most plants and animals are easily separated one from the other, lower forms are not easily distinguished. This is because both plants and animals have descended from a common ancestor.

4. Plants and animals are extremely closely interdependent in many respects and their inter-relationship is indispensable to both.

CHAPTER II

CLASSIFICATION

WHAT IS CLASSIFICATION?

Over a million different kinds of animals and about 300,000 kinds of plants are already known from the world. It is estimated by competent

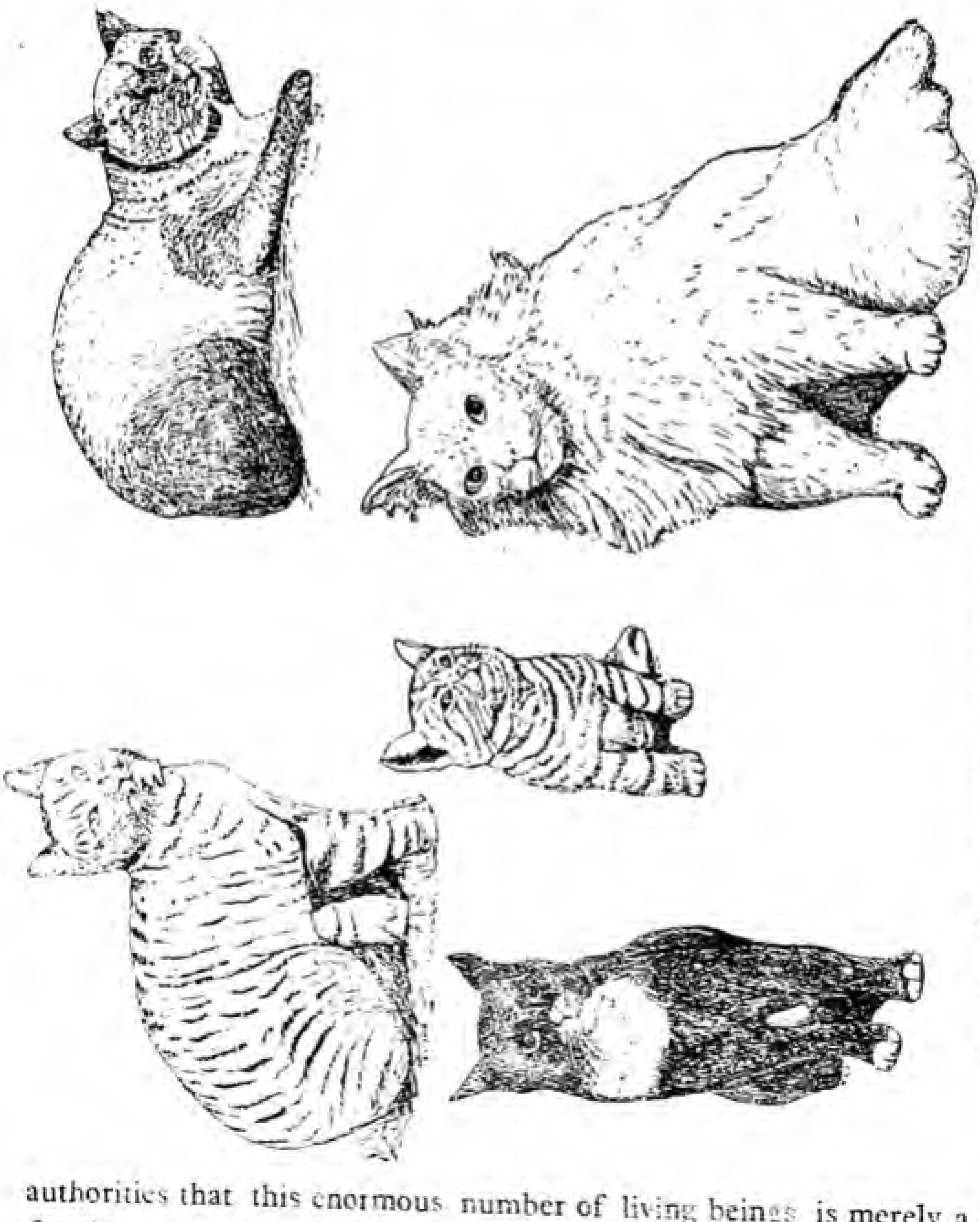

FIG. 11. There are several kinds of cats: the manx, the Siamese cat, short-haired black cat, short-haired striped cat, white long-haired angora cat, brown cat, etc. All breed with each other and belong to the same species, viz. domestic cat—*Felis domesticus* (*Redrawn from Davenport*).

authorities that this enormous number of living beings is merely a minute fraction, perhaps one-tenth of that which still awaits discovery. If we are

to speak of such a vast number of animals, it becomes necessary to arrange them in some sort of order. For convenience in study, animals are divided into larger or smaller groups. These groups are then subdivided into convenient sections.

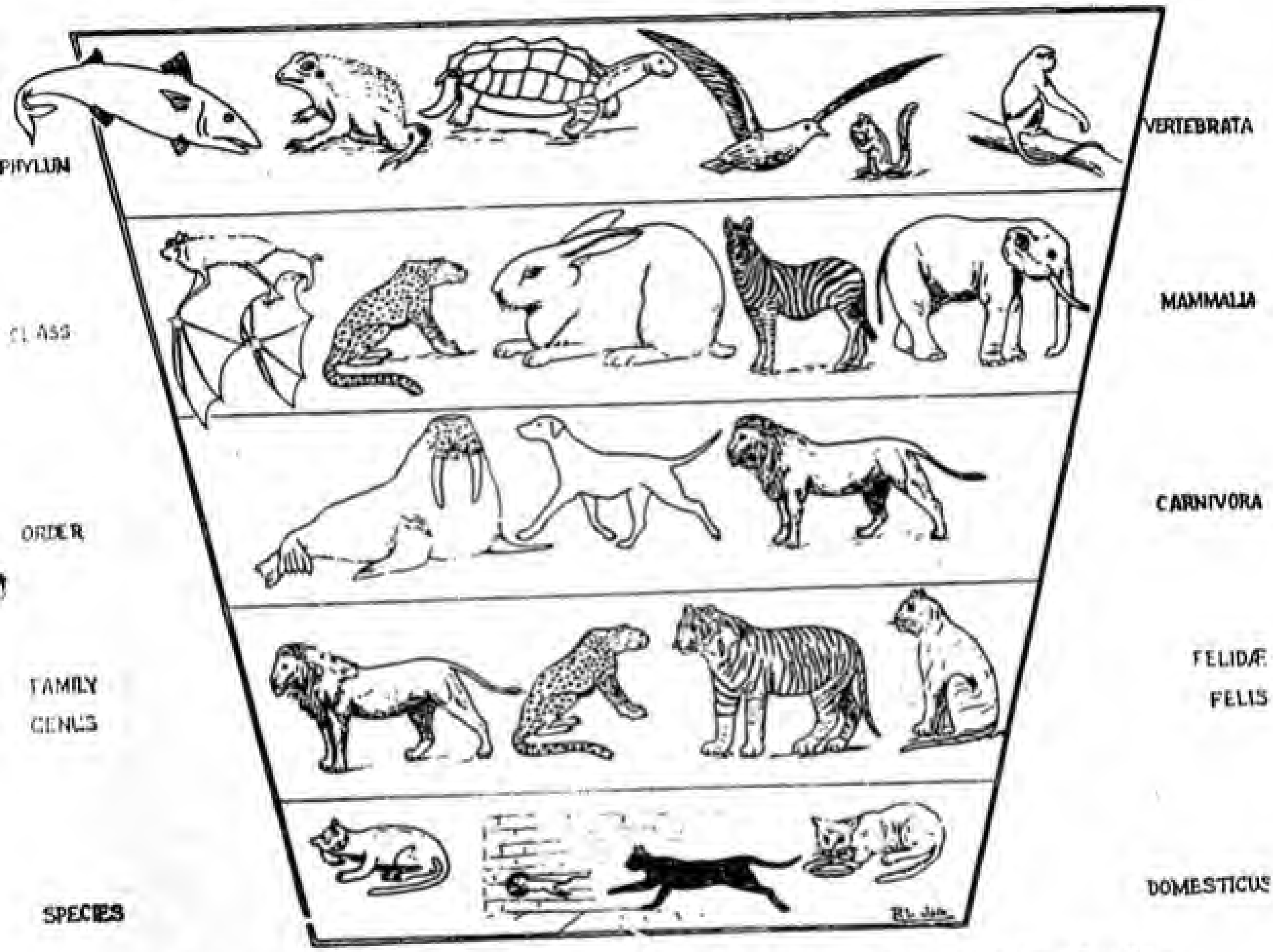

FIG. 12. Classification Animals are classified into phyla, classes, orders, families, genera and species. Fish, frog, tortoise, bird, squirrel and monkey resemble one another in having a vertebral column; they all belong to the Phylum Vertebrata. Bat, leopard, rabbit, zebra and elephant resemble one another more closely than to bird or fish; they belong to the same class—Mammalia or animals that have mammary glands and produce milk. Walrus, dog and lion resemble each other more closely than to zebra or rabbit. They are all flesh-eating animals and belong to the order Carnivora. Among them the lion, leopard, tiger and cat have greater resemblance to each other than to the dog; they belong to one family: Felidae but different genera. The various varieties of the domesticated cat all belong to one species.

All individuals, which have essentially the same structure and life-history, belong to one ***species***. There are, for example, hundreds of thousands of individuals of the common domestic cats, (Fig. 11.) some of which are black, some grey, others brown, still others white, some with bushy hairs and so on. Inspite of these minor differences they all have essentially

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the same proportion of body, bones, etc. and freely *interbreed* and so belong to one ***species***.

Now there are also *many* species of cats, which are distinct from each other and do *not* interbreed, but possess certain well marked common fundamental characters and are therefore grouped together into one ***genus***. Thus even a casual observer will find that the house cat, the tiger, the lion and the leopard each belongs to a different species but all the same are cats and thus belong to one genus. He will also note that the resemblance between these cat-like animals and the dogs are less striking but the differences are more marked. Cats and dogs belong to different genera. Several genera which resemble one another are grouped together into ***families***. Cats and dogs resemble each other more closely than a horse or a cow resembles a dog or cat. Horse and cow belong to a different family. Similarly a number of families, which have certain common characters, constitute an ***order***. Several orders which resemble one another are similarly grouped into a ***class*** and the classes into a ***phylum*** (Fig. 12). Several phyla in their turn constitute the ***Animal Kingdom***. The animal and plant kingdoms together make up the living world.

When animals are grouped in this way on the basis of structure and affinity, we ***classify*** them. Classification or ***taxonomy*** is really sorting out and arranging animals according to their blood relationship in a graded series of groups, each with members which are essentially alike. This grading is carried out in such a way that the simplest and the most ancient forms are placed at the bottom of the series, with the complex and more recent at the top (Fig. 46). The utility of classification lies in the fact that it brings order out of chaos and also tells us about the inter-relationship of animals. Taxonomy or as it is also called ***systematic zoology*** is therefore not a mere cataloguing of animals. It is however not an end in itself but a means to an end. It is the basis for all other work.

THE CLASSIFICATION OF THE ANIMAL KINGDOM*

The Animal Kingdom is divided into a number of phyla and classes. In the following synopsis some of the more important ones are included.

* The total number of Phyla recognized at the present time is twenty. Of these the following minor Phyla are not dealt with in this book :

1. CTENOPHORA (comb jellies), 2. NEMERTINEA (ribbon worms), 3. GORDIACEA ("horsehair" worms or hair snakes), 4. ACANTHOCEPHALA (spiny-headed worms), 5. KINORHYNCHA (echinodera worm), 6. TROCHELMINTHES (wheel animalcule or rotifers), 7. CHAETOGNATHA (arrow worms), 8. BRYOZOA (moss animals), 9. BRACHIOPODA (lamp shells) and 10. PHORONIDEA (phoronis worms).

Kingdom ANIMALIA

A. Subkingdom PROTOZOA. (Fig. 13) Unicellular animals without tissues or organs.

Phylum 1. PROTOZOA. An individual is a *single* cell or is a colony of cells, similar in structure and performing all functions of life independently of each other. Generally microscopic in size.

Class (*i*) SARCODINA (=Rhizopoda) Locomotion by simple streaming of pseudopodia. Example: *Amoeba* (Fig. 13).

Class (*ii*) MASTIGOPHORA (=Flagellata) Locomotion by whip-like flagellum. Example: *Euglena* (Fig. 13).

Class (*iii*) SPOROZOA. No locomotion. All parasitic in other animals. Example: *Haemamœba* (=*Plasmodium*) or malarial parasite. In the blood of man and other animals.

Class (*iv*) CILIATA. Hair-like ciliary processes on the surface used in locomotion. Example: *Paramecium* (Fig. 13).

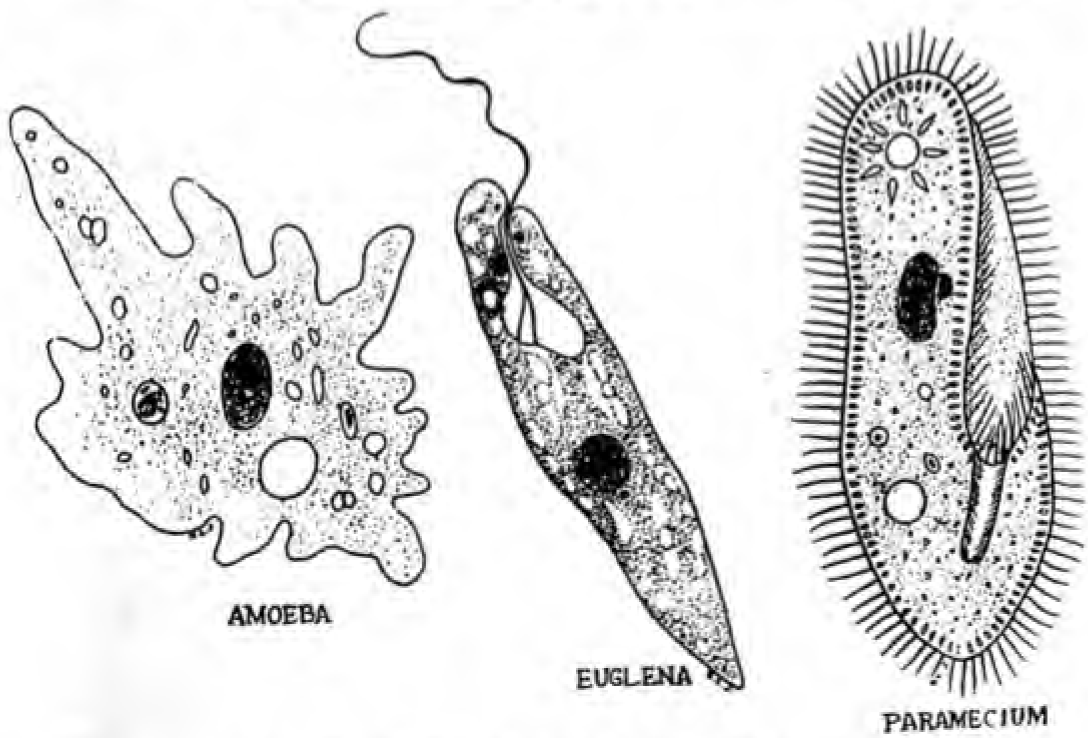


FIG. 13. Phylum Protozoa. Unicellular animals.

B. Subkingdom METAZOA. Multicellular animals. Animals with many different cells in their body, arranged into tissues, each performing a different function.

Division I. PARAZOA. A side branch of animals, without a distinct gut or digestive cavity.

Phylum 2. PORIFERA. Sponges. (Fig. 14) Aquatic, mostly marine and sedentary animals, often branched like a tree and reproducing by budding, with many pores on the surface, leading into a system of water canals opening to the outside by an osculum.

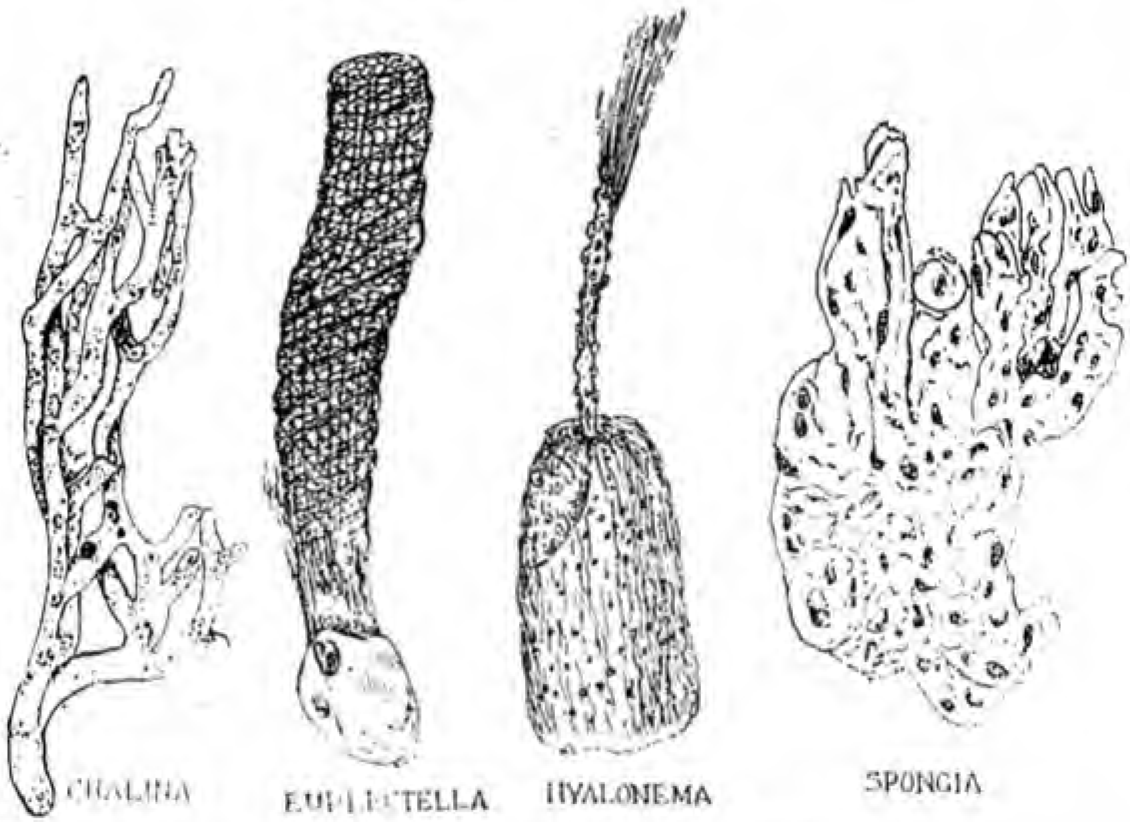


FIG. 14. Phylum Porifera. Sponges.

Class (*i*) CALCAREA. Sponges with minute spicules of calcium carbonate for skeleton. Example : *Sycon*.

Class (*ii*) HEXACTINELLIDA. Glass sponges. Minute spicules of six-rayed, silicious material. Examples : *Hyalonema*, *Euplectella*.

Class (*iii*) DEMOSPONGIAE. No skeleton or with silicious or horny (spongin) spicules. Example : *Euspongia* the common bath sponge.

Division II. ENTOZOA. Animals with a distinct digestive tract or enteric cavity.

Phylum 3. COELENTERATA. (Figs. 6, 15). Aquatic, mostly marine. Without head or anus but with a mouth surrounded by

tentacles and opening into a digestive cavity. No separate body cavity. Stinging cells often present. Very often sessile and branched like a plant.

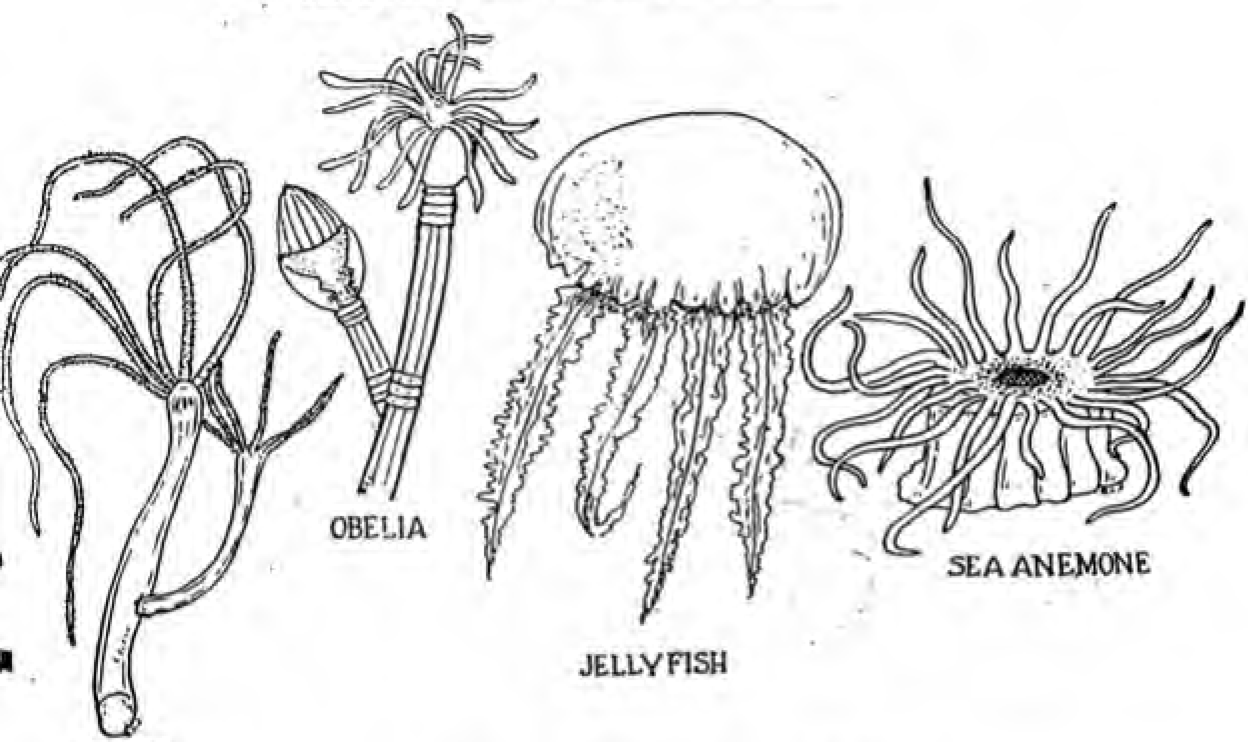


FIG. 15. Phylum Coelenterata. Polyps and jellyfishes.

Class (*i*) HYDROZOA. Hydroid polyps and some medusae. Digestive cavity simple and sac-like. Examples : *Hydra*, (freshwater) and *Obelia* (marine), also the stinging coral *Millipora* (marine).

Class (*ii*) SCYPHOZOA. Jellyfishes. Body bell or umbrella-shaped. Digestive cavity with branched canals. Example : *Aurelia*.

Class (*iii*) ANTHOZOA (= Actinozoa). Sea-anemones, corals, polyps. Digestive cavity divided by radial partitions. Examples : *Metridium* sea-anemone and *Gorgonia* sea-fan.

Phylum 4. PLATYHELMINTHES. Flatworms. (Fig. 16) Leaf or ribbon-shaped, soft worms, with branched digestive tract but no anus.

Class (*i*) TURBELLARIA. Free-living ribbon-shaped worms in fresh-water. Example : *Planaria*.

Class (*ii*) TREMATODA. Flukes. Body leaf-shaped with suckers or hooks and with a two-branched gut. Parasitic worms. Example : *Fasciola* (liverfluke).

Class (*iii*) CESTOIDEA. Tapeworms. Flat, ribbon-like worms with numerous segment like proglottids, each having complete

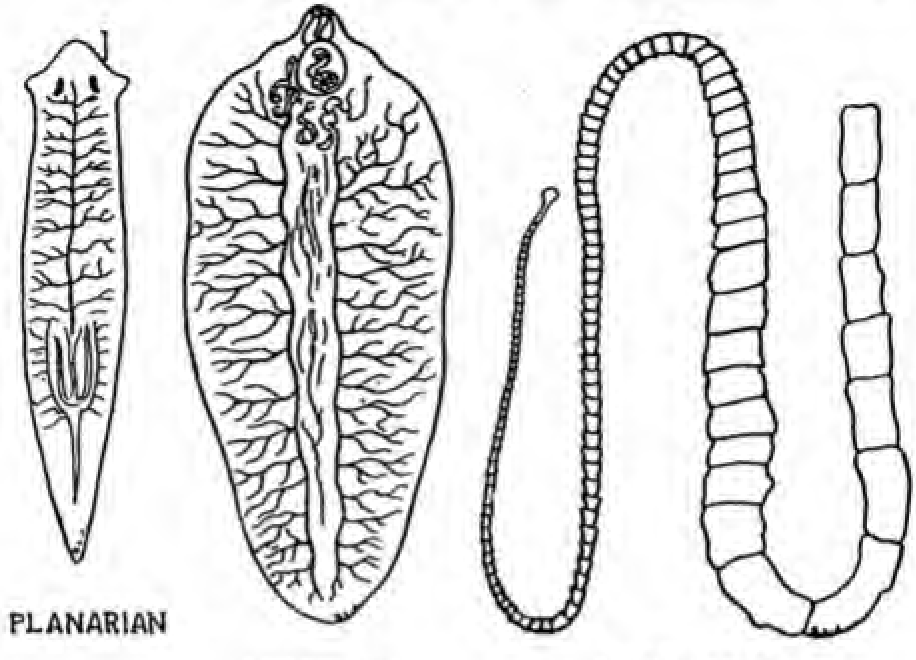


FIG. 16. Phylum Platyhelminthes. Flatworms.

reproductive organs. No mouth or gut. All parasitic. Example : *Taenia*.

FIG. 17. Phylum Nemathelminthes. Threadworms.

Phylum 5. NEMATHELMINTHES. (Fig. 17). Nematode or round worms. Body elongate, slender and thread-like. Gut complete. Free-living or parasitic. Examples : *Ascaris* and *Ancylostoma* hookworm.

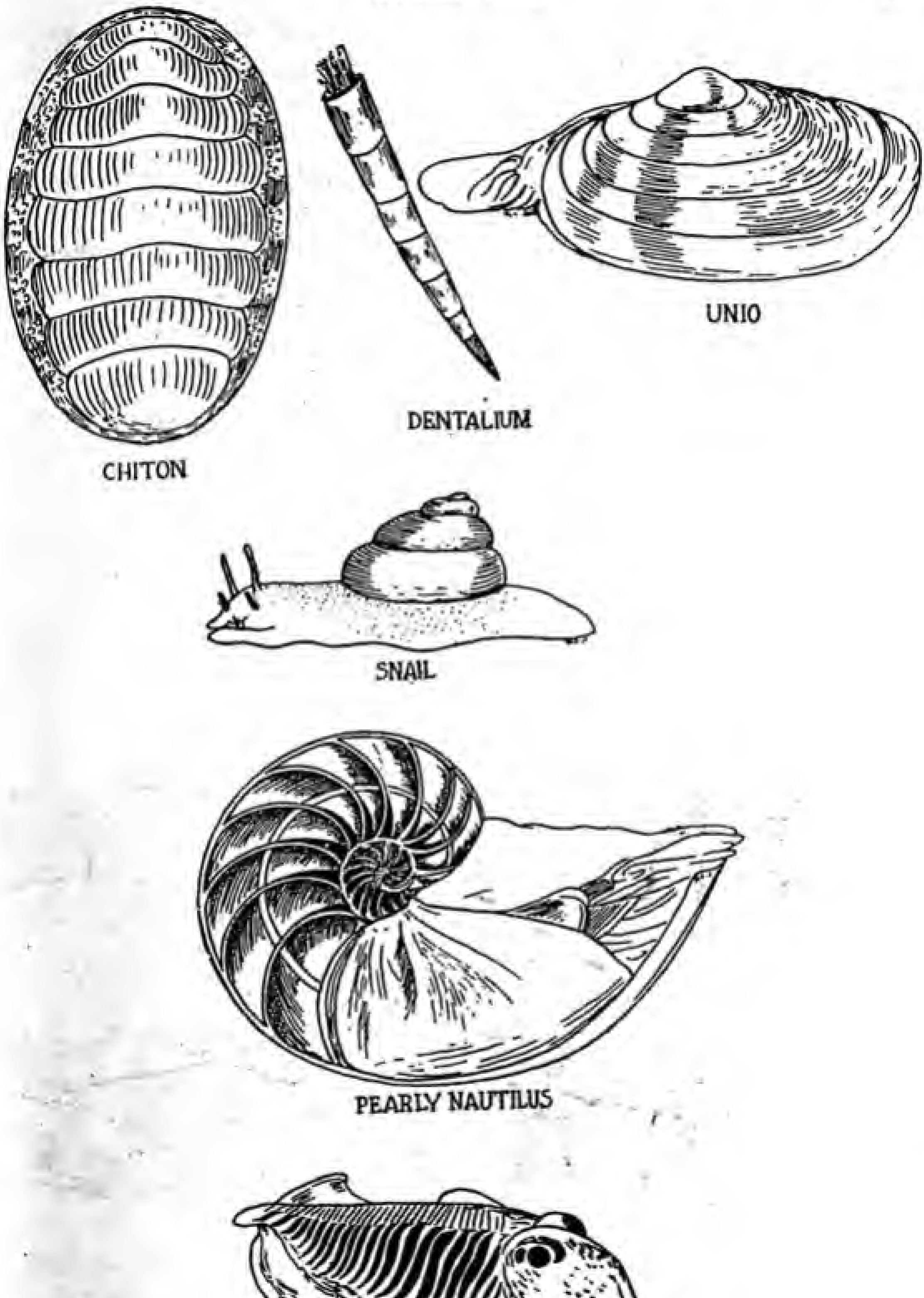


FIG. 18. Phylum Mollusca.

Phylum 6. MOLLUSCA. (Figs. 18). Soft body covered by a mantle, which secretes a calcareous shell.

Class (*i*) AMPHINEURA. Shell in eight pieces, body elongate. Example : *Chiton.*

Class (*ii*) SCAPHOPODA. Shell tubular and like the tusk of an elephant. Example : *Dentalium.*

Class (*iii*) PELECYPODA. Bivalved hinged shells ; no head. Examples : Oysters and *Unio.*

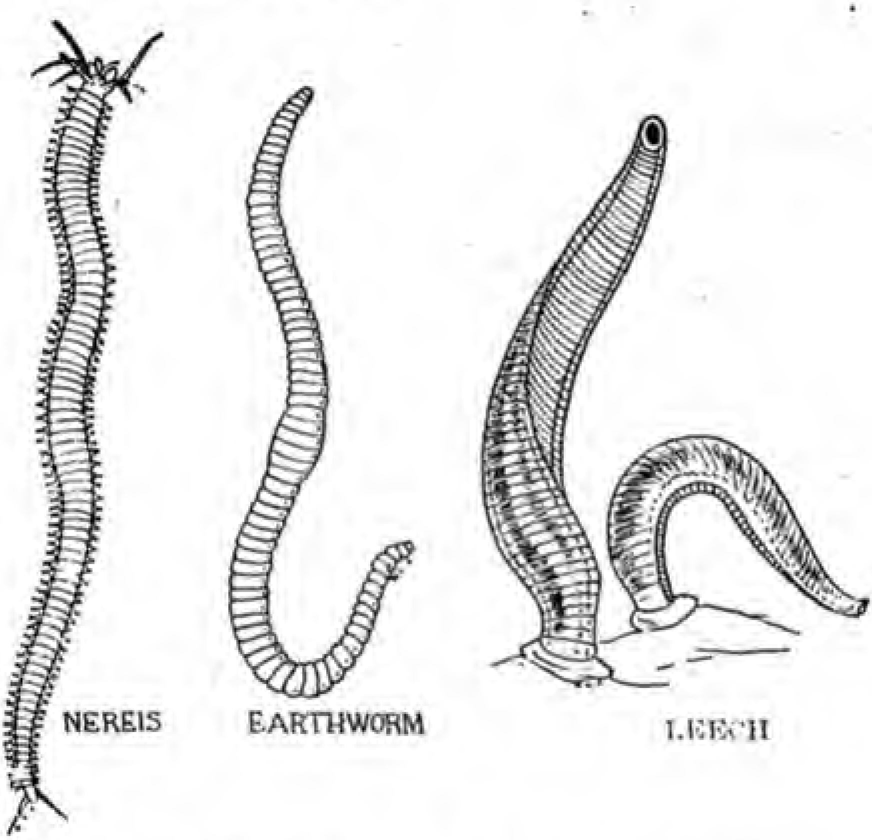


FIG. 19. Phylum Annelida. Roundworms.

Class (*iv*) GASTROPODA. Conch shells. Shell univalve, spirally coiled ; body also spiral, asymmetrical. Head distinct. Examples : Snails, cowries, conches, *Pila*, *Helix.*

Class (*v*) CEPHALOPODA. Shell internal. Mouth with jaws and with 8-10 tentacles or arms. Examples : *Octopus* cuttlefish, squids, *Nautilus.*

Phylum 7. ANNELIDA. Segmented worms. (Fig. 19) Body elongate with many segments and bristles for locomotion. Digestive tract complete. Closed blood vascular system dorsal to gut. Brain and nerves well developed, nerve cord ventral to gut. Free-living.

Class (*i*) POLYCHAETA. Body conspicuously segmented, with lateral processes called *parapodia*, bearing bristles for locomotion. Marine worms. Example: *Nereis*.

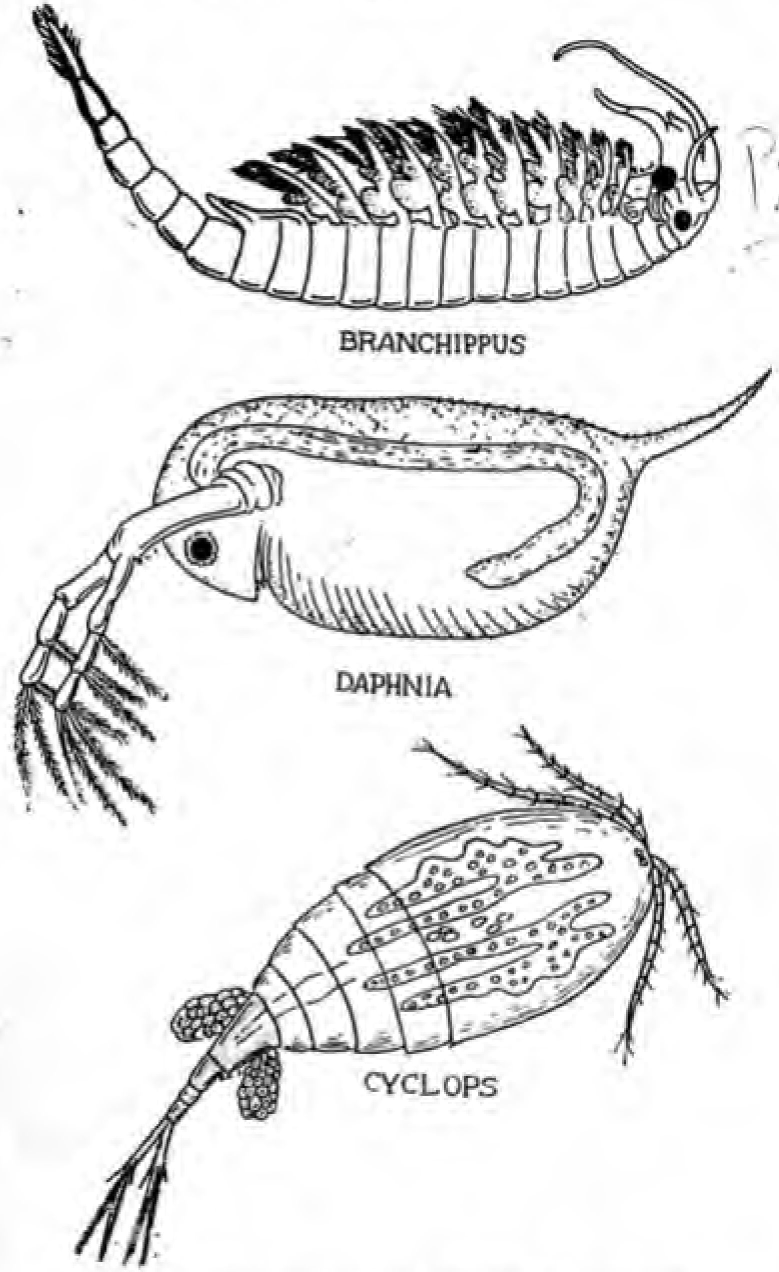


FIG. 20. Phylum Arthropoda. Class Crustacea.

Class (*ii*) OLIGOCHAETA. Earthworms. No parapodia. In moist soil. Examples: *Lumbricus*, *Pheretima*.

Class (*iii*) HIRUDINEA. Leeches. Flattened body with segmentation not conspicuous. No parapodia or setae. Often blood-sucking. Example: *Hirudinaria*, leech.

Phylum 8. ARTHROPODA. (Figs. 20-27) The largest and the most dominant of all phyla. Animals with jointed legs.

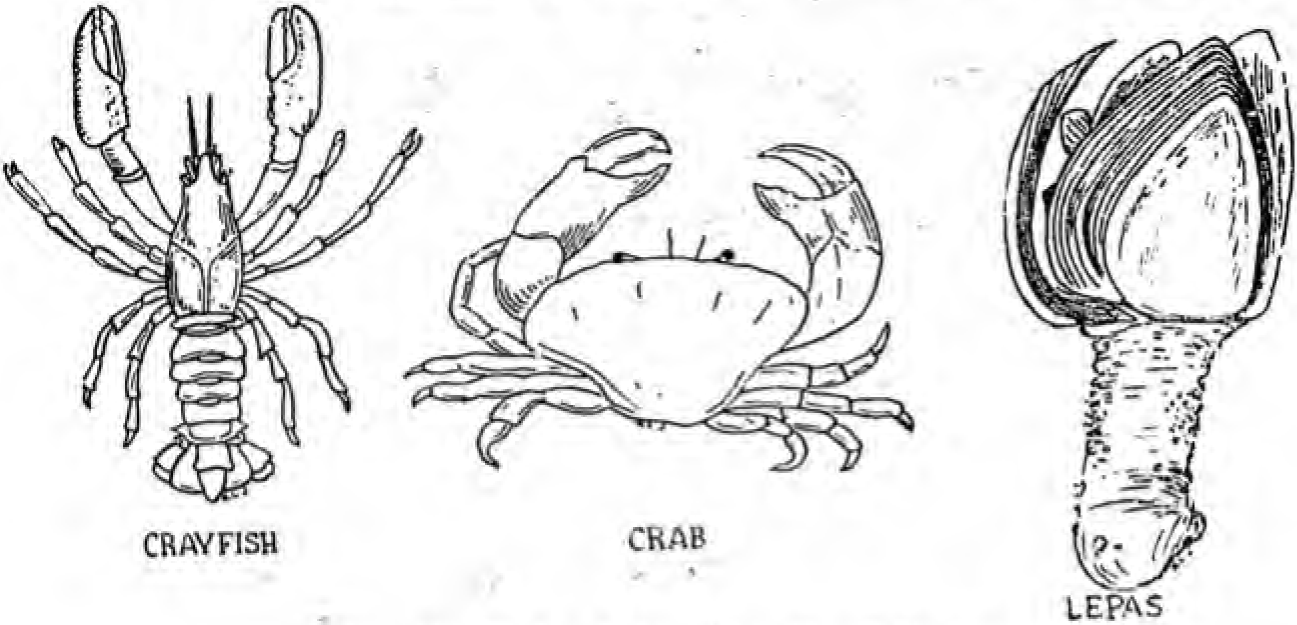


FIG. 21. Phylum Arthropoda. Class Crustacea.

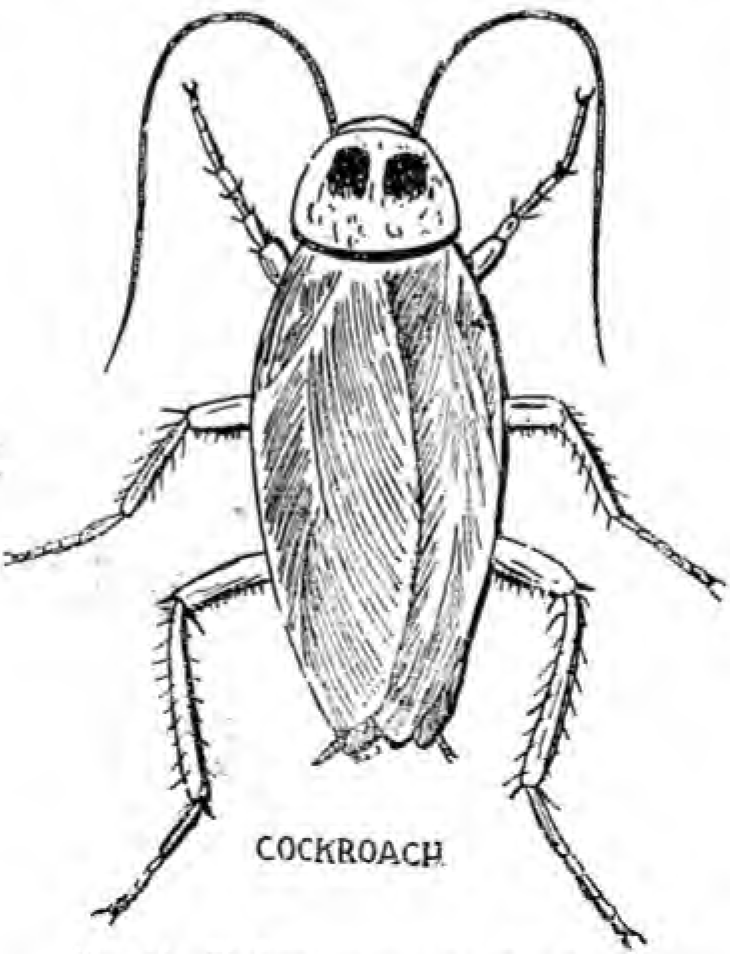


FIG. 22. Phylum Arthropoda. Class Insecta.

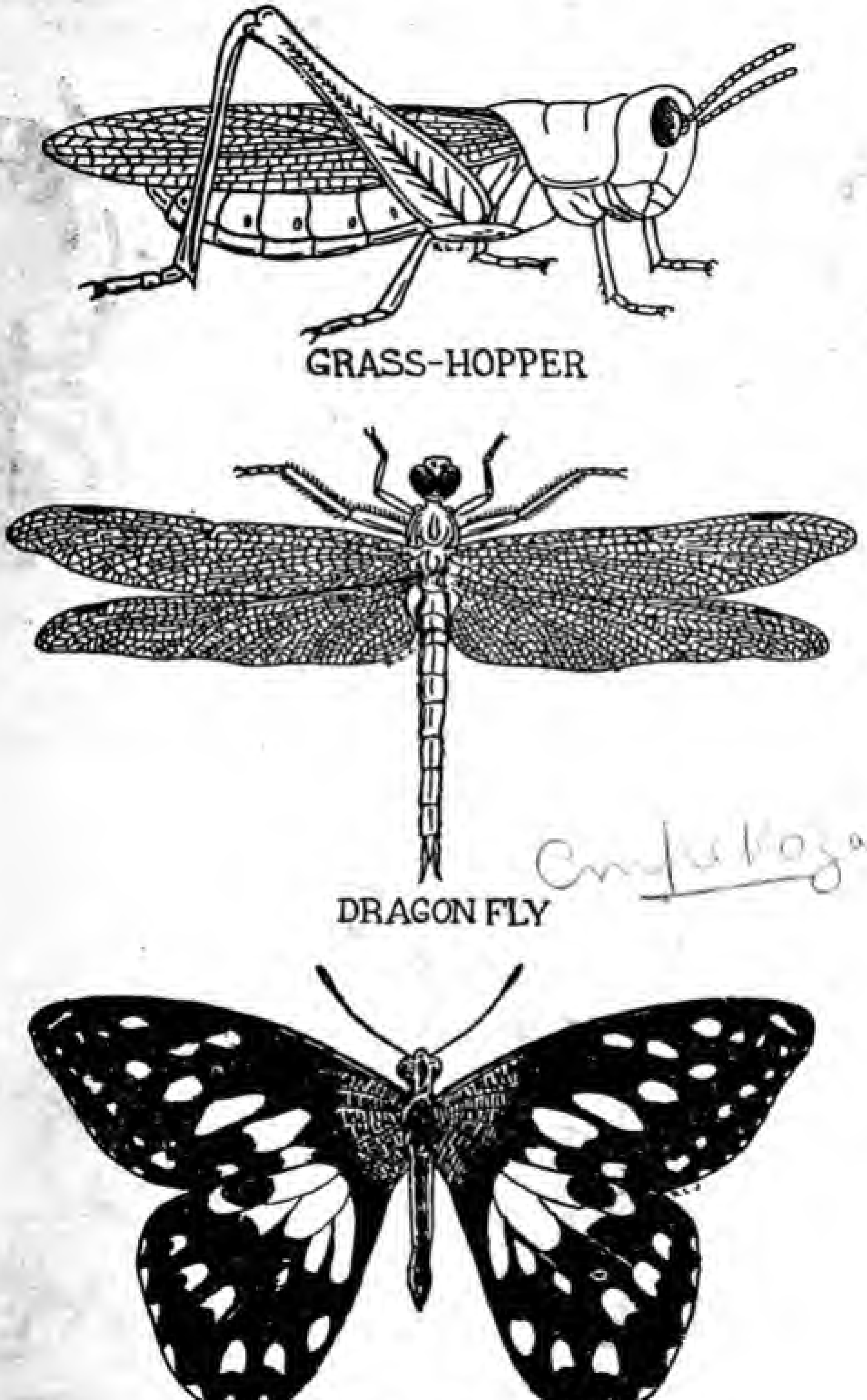


FIG. 23. Phylum Arthropoda Class Insecta.

Chitinous exoskeleton. Heart dorsal and nervous system ventral to gut. Respiration by gills or tracheae.

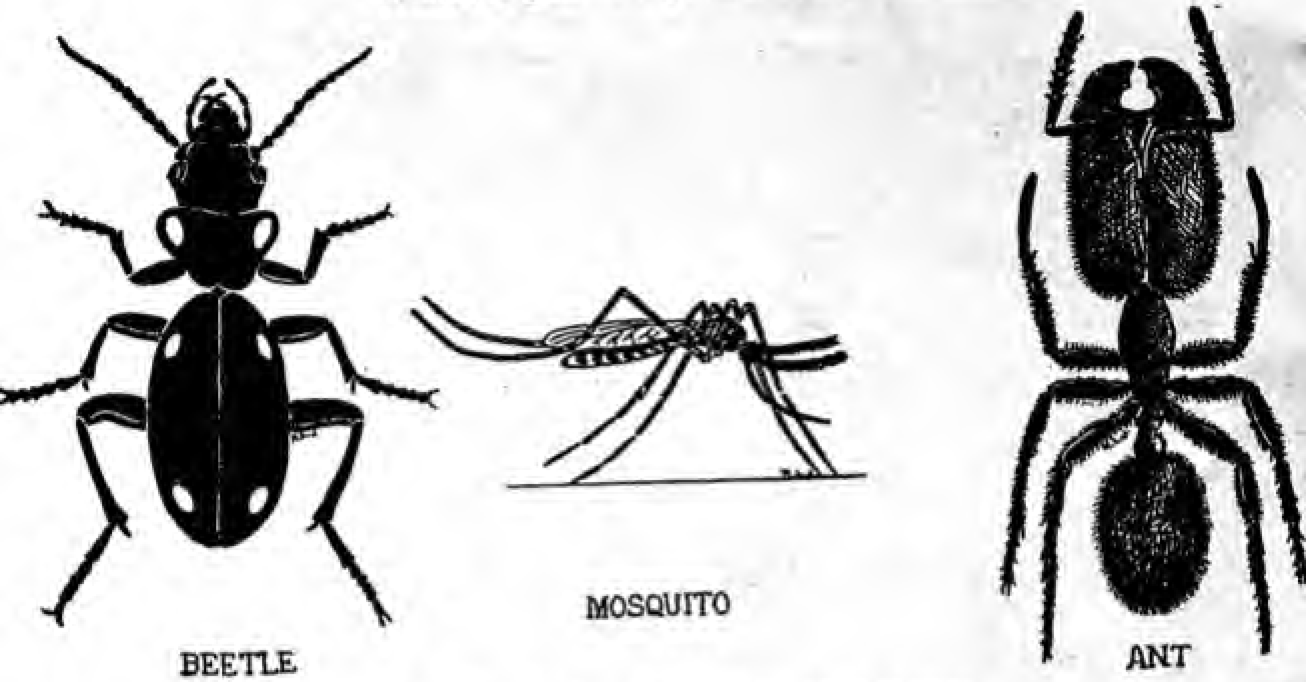


FIG. 24. Phylum Arthropoda. Class Insecta.

Class (*i*) CRUSTACEA. (Figs. 20, 21) Antennae two pairs. Body often with carapace or a dorsal shield. Mostly aquatic and

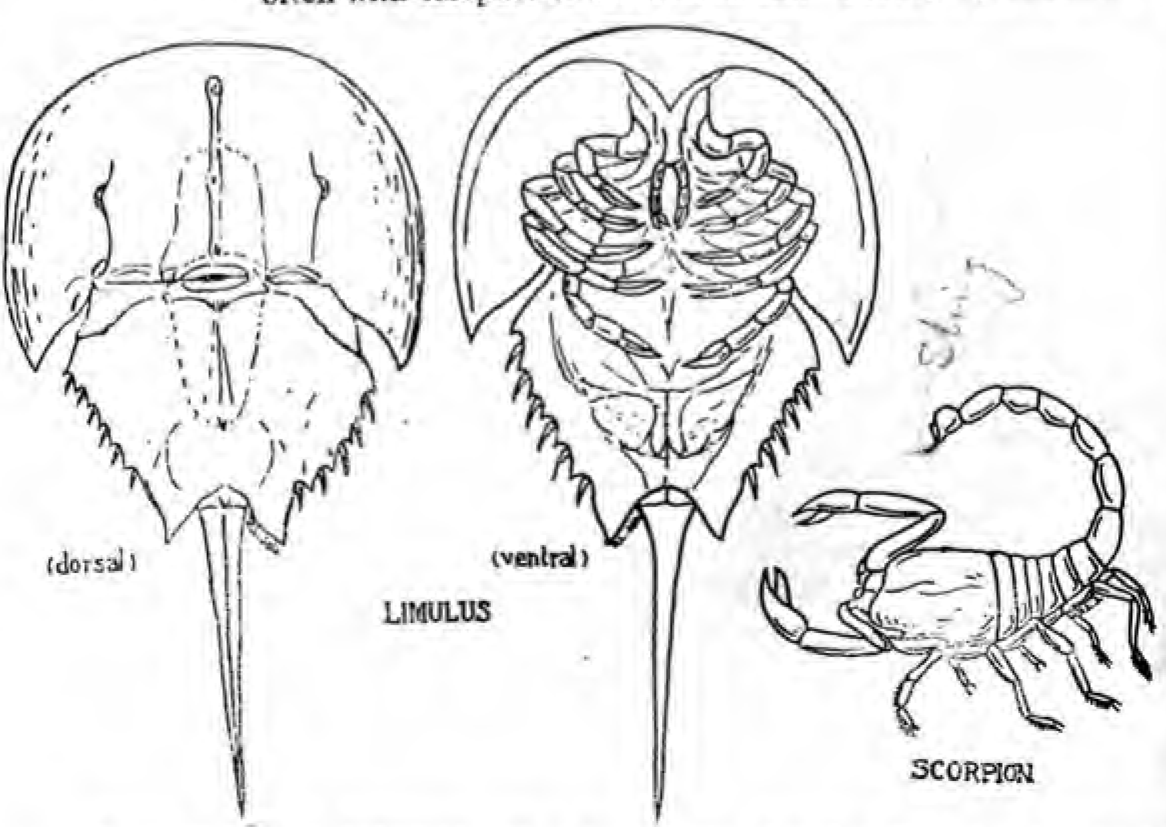
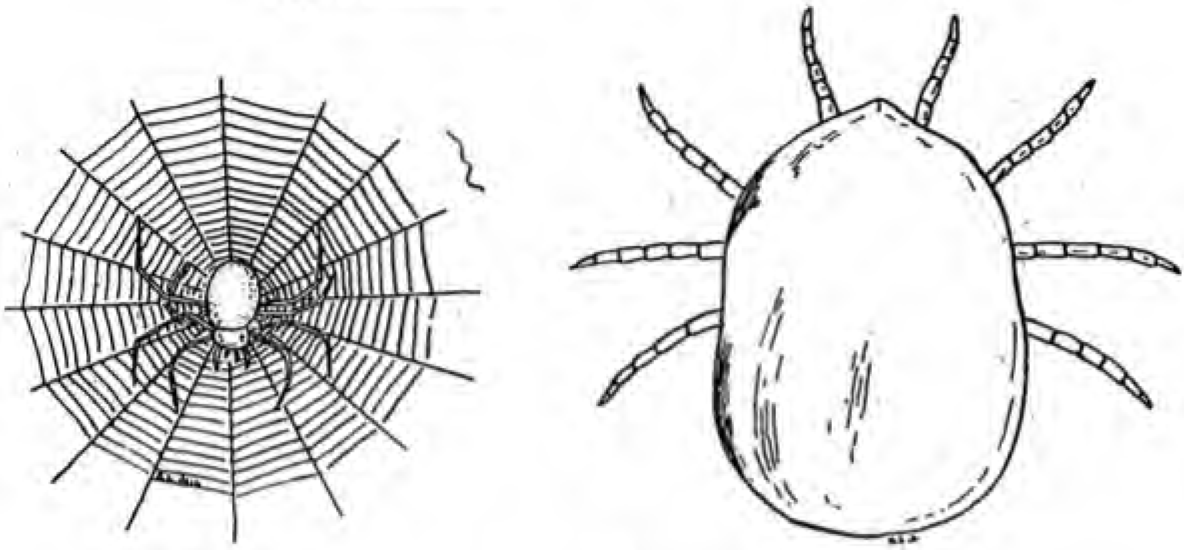


FIG. 25. Phylum Arthropoda. Class Xiphosura: *Limulus*. Class Arachnoidea: Scorpion.

marine. Examples: Crabs, prawns, lobsters, shrimps, *Branchippus*, *Cyclops*, waterfleas, *Daphnia*, sowbugs, *Lepas* barnacles.



SPIDER TICK

FIG. 26. Phylum Arthropoda. Class Arachnoidea.

Class (*ii*) INSECTA (=Hexapoda). Insects. (Figs. 22-24) One pair of antennae. Head, thorax and abdomen distinctly demarcated. Legs three pairs. Often one or two pairs

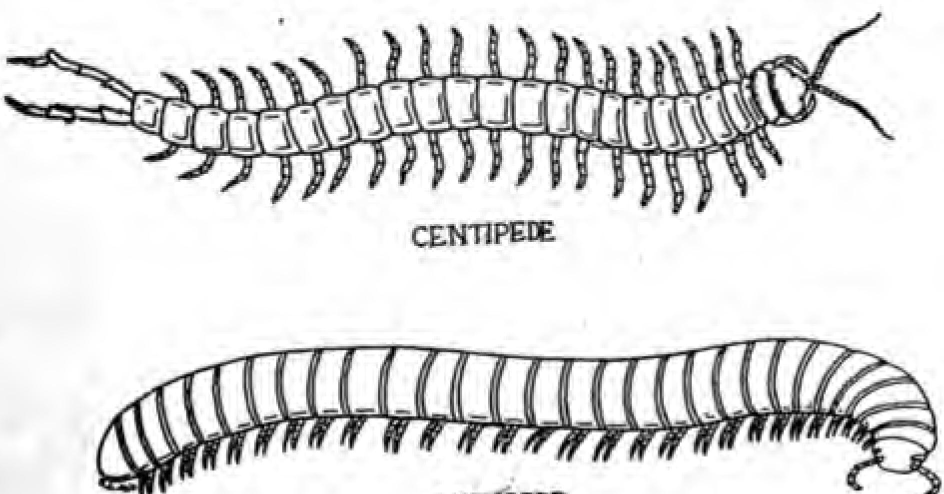


FIG. 27. Phylum Arthropoda. Class Chilopoda: Centipede. Class Diplopoda: Millipede.

of wings. The largest class of animals comprising nearly three-quarters of a million known species. Often social animals, with brain development next to man.

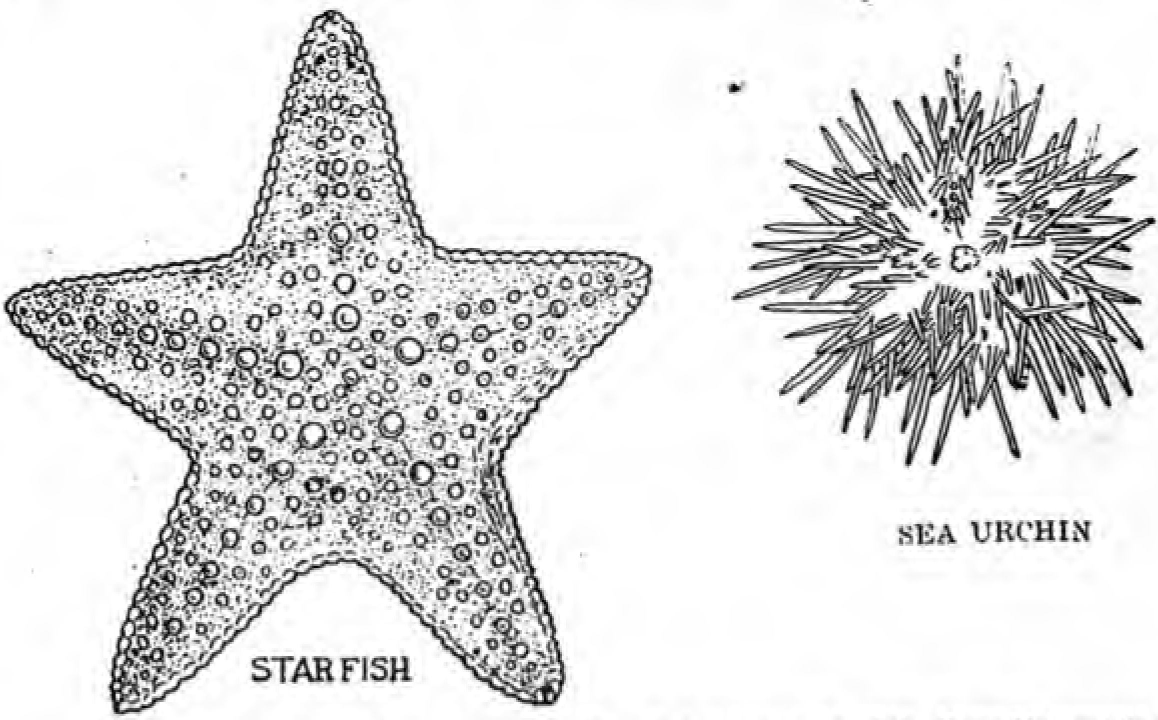


Fig. 28. Phylum Echinodermata. Class Asteroidea: Starfish. Class Echinoidia: Sea urchin.

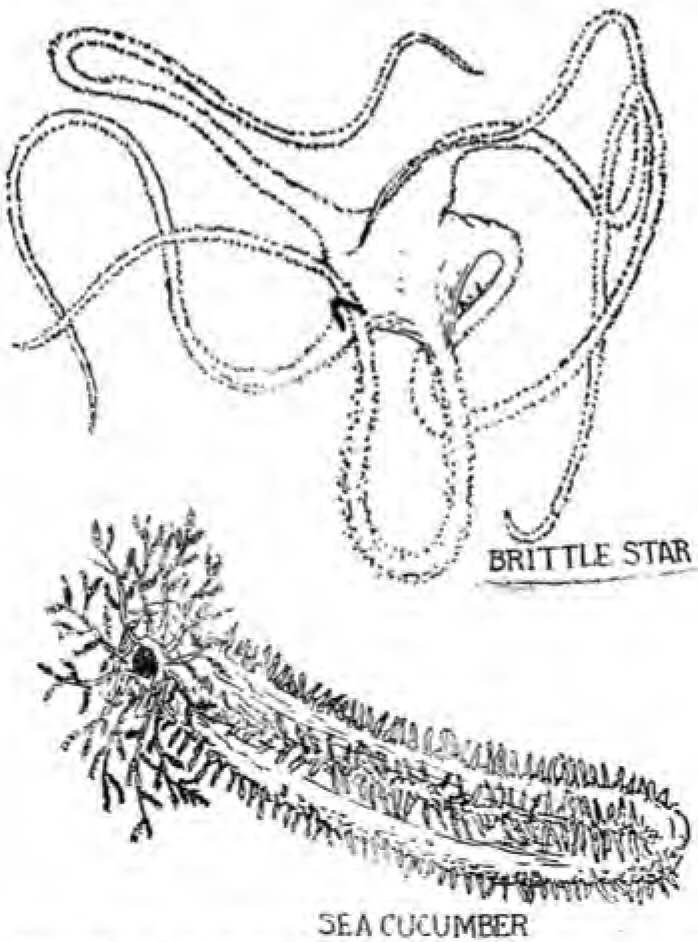


Fig. 29. Phylum Echinodermata. Class Ophiuroidea: Brittle-star. Class Holothuroidea: Sea cucumber.

Examples: grasshopper, locust, dragonfly, cockroach, termites, beetles, bugs, flies, mosquitoes, butterflies, ants, bees, wasps.

Class (*iii*) ARACHNOIDEA. (Figs. 25, 26) No antennae. Head and thorax fused together into a cephalothorax. Legs four pairs. Never with wings. Examples: spiders, scorpions, mites, ticks, kingcrabs.

Class (*iv*) CHILOPODA. (Fig. 27) One pair of antennae. Each segment of body with one pair of legs. Example: *Scolopendra* centipedes.

Class (*v*) DIPLOPCDA. (Fig. 27) One pair of antennae. Each segment of body with two pairs of legs. Example: *Julus* millipedes.

Phylum 9. ECHINODERMATA (Fig. 28, 29) Radial animals. All marine. With calcareous spines and plates imbeded in the skin. A system of water vascular canal connected to tube feet used in locomotion.

Class (*i*) ASTEROIDEA. Starfishes. Body of the conventional figure of a star, five-rayed or armed. Mouth at the centre. Example: *Asterias*.

Class (*ii*) OPHIUROIDEA. Brittle-stars. Body distinctly divided into long slender and articulated arms and central disc. Example: *Ophiura*.

Class (*iii*) ECHINOIDEA. Sea urchins. Body hemispherical or cake-like. Spines prominent. Example: *Strongylocentrotus*.

Class (*iv*) HOLOTHUROIDEA. Sea cucumbers. Body elongate or worm-like, soft and fleshy. Examples: *Holothuria* and *Cucumaria* sea cucumber

Class (*v*) CRINOIDFA. Sea lilies. Body flower-shaped; often fixed. Example: *Antedon*.

Phylum 10. CHORDATA. Animals with an axial elastic rod-like *notochord* as skeleton, present either throughout the life or at some stage of development. Nerve cord tubular, single and dorsal to the gut. Heart ventral to the gut. Pharynx pierced by gill slits either in the embryo or throughout life. Liver, developed from the gut, receives the blood from it before passing it on to the heart.

Section (A) ACRANIA (=Protochordata). (Fig. 30) Without cranium or brain case, jaws or vertebrae. Small marine forms, a sort of connecting link between the non-chordate phyla so far enumerated and the true Chordata.

Subphylum (*i*) *Hemichordata*. Tongue worms. Marine worm-like forms with a fleshy proboscis and short notochord at the anterior end. Example: *Balanoglossus*.

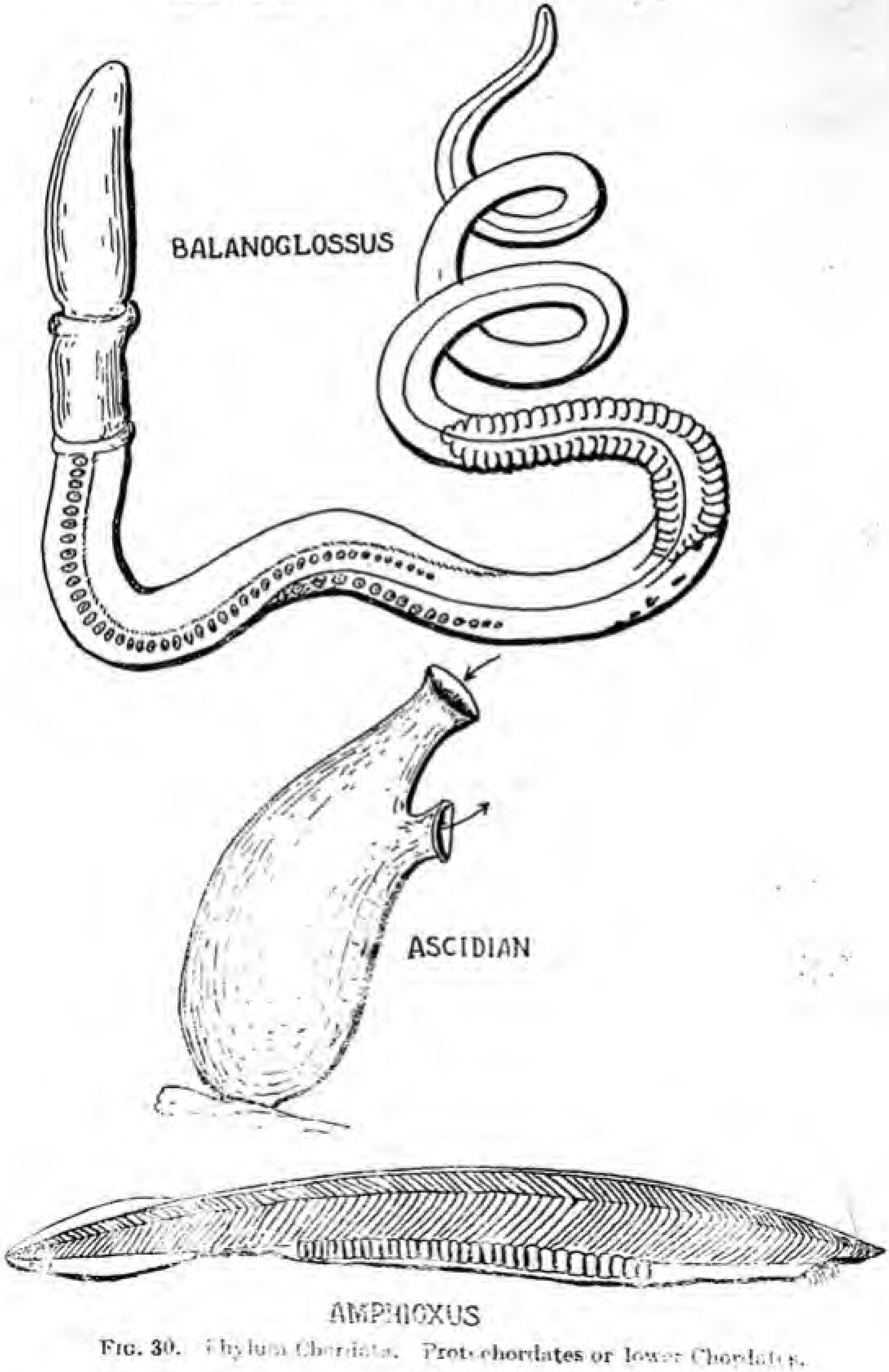


Fig. 30. Phylum Chordata. Protochordates or lower Chordates.

Subphylum (*ii*) *Urochordata*. Tunicates. Larva tadpole-like, with notochord in the tail. Adult degenerate, without nerve cord and notochord. Example: *Herdmania* sea-squirts.

Subphylum (*iii*) *Cephalochordata*. Slender, fish-like, segmented marine animals with notochord and nerve cord extending the whole length of the body. Permanent gill slits. Example: *Amphioxus*.

Section (B) CRANIATA. Vertebrates. With cranium or brain case and vertebrae. Dorsal nerve cord anteriorly dilated to form a brain.

Subphylum (*a*) *Agnatha*. Without jaws, paired fins or limbs. Several gill arches present

Class CYCLOSTOMATA. (Fig. 31) Without jaws, paired fins or limbs. Fishlike forms having only median fins, circular suctorial mouth and unpaired nasal opening. Examples: *Petromyzon* and *Myxine*.

Subphylum (*b*) *Gnathostomata*. Vertebrates with paired fins or limbs and the first pair of gill arches modified as jaws.

Superclass *PISCES*. Fishes. (Figs. 31, 32) Median fins supported by fin rays. Nasal capsule not communicating with the mouth cavity. Skin generally covered by scales. One auricle in the heart. Aquatic.

Class (*i*) CHONDRICHTHYES. Cartilagenous fishes with jaws. Gill slits fewer than in the Cyclostomata. Body covered by plate-like (placoid) scales. Notochord strengthened by cartilagenous vertebræ. Examples: Sharks, *Scoliodon* dogfish, rays, torpido fish, etc.

Class (*ii*) OSTEICHTHYES. True bony fishes with gills covered by operculum. Examples: *Labeo*, plaice, mackerel, masheer, etc.

Superclass *TETRAPODA*. Terrestrial vertebrates having four limbs instead of fins: two pairs of five-toed legs. Nasal cavity communicating with mouth cavity. Heart with two auricles. Lungs replace gills.

Class (*i*) AMPHIBIA (=Batrachia). (Fig. 33) Gills present only in the early stages. Bridge the gap between aquatic and terrestrial vertebrates. Breed in water and undergo metamorphosis. Capable of living both in water and on land.

Never marine. Examples: *Rana* frogs, *Bufo* toads, *Necturus*, salamanders, sirens, newts, etc.

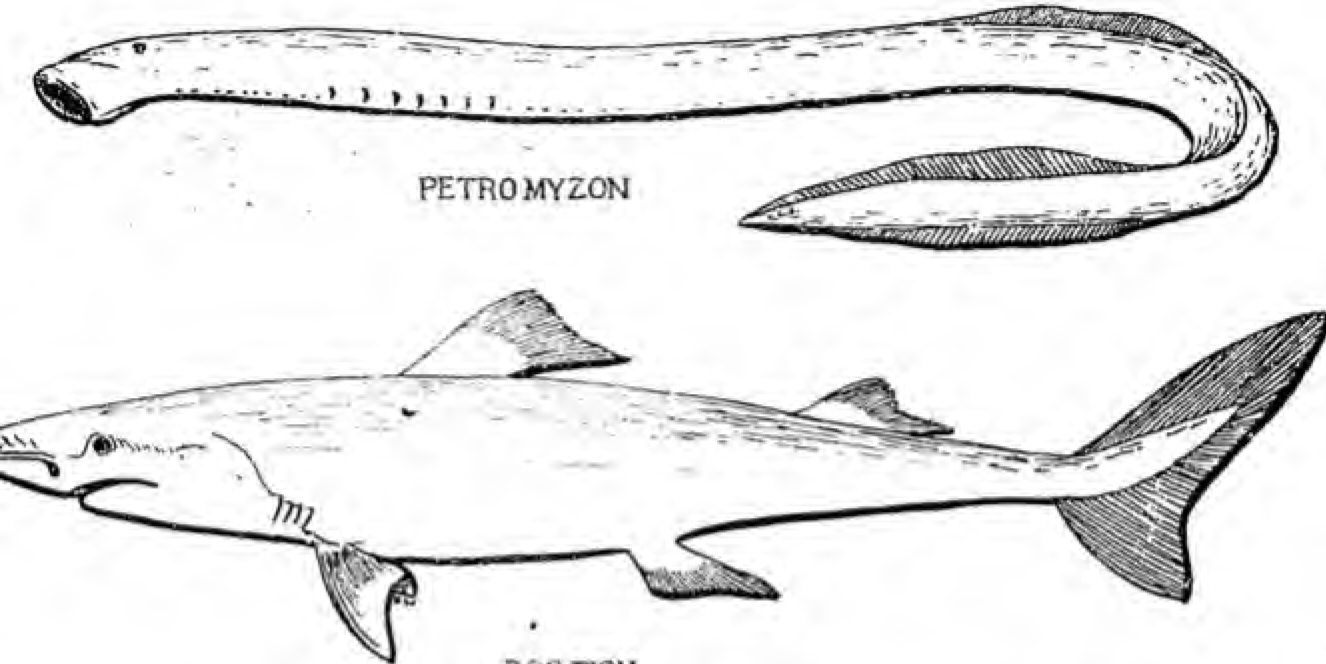


Fig. 31. Phylum Chordata. Class Cyclostomata. Class Chondrichthyes.

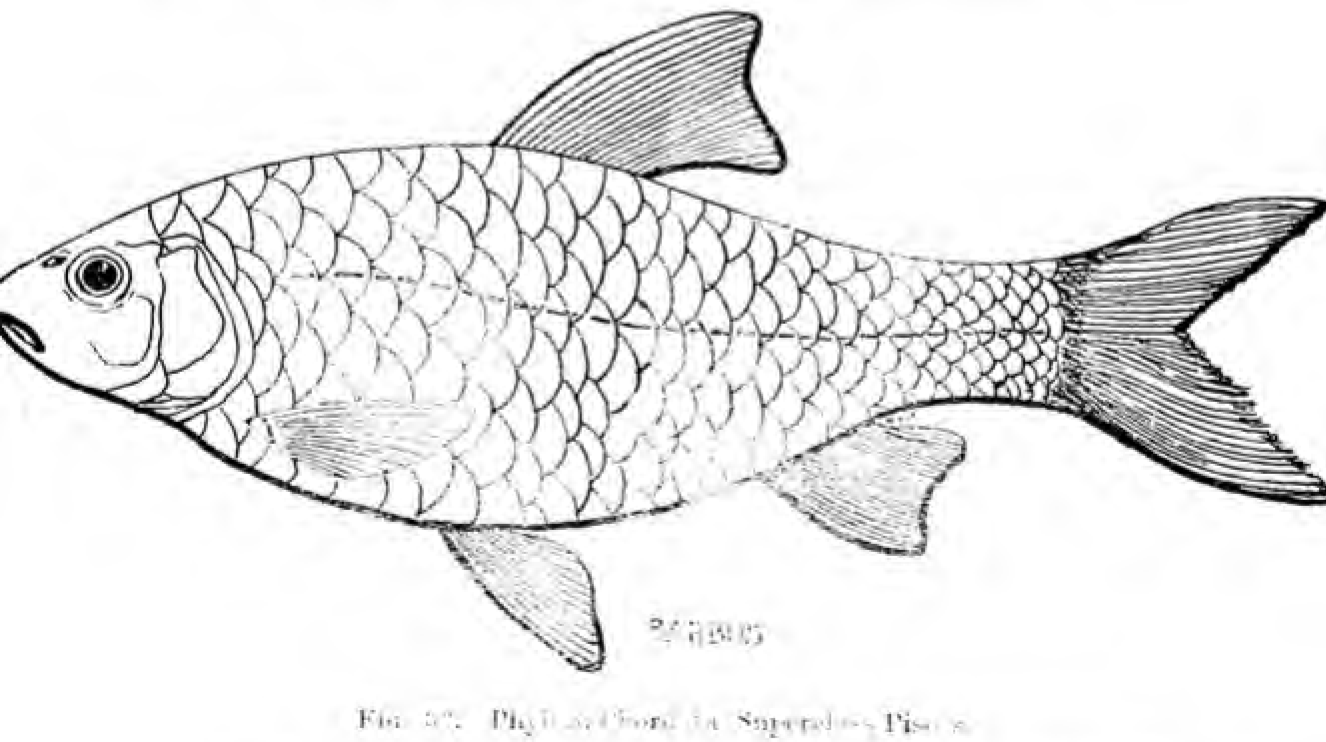


Fig. 32. Phylum Chordata. Superclass Pisces.

Class (*ii*) Reptilia (Figs. 34, 35, 36): Mostly terrestrial tetrapods without metamorphosis, never laying eggs in water. Skin covered by scales or plates. Respiration by lungs.

Examples: Extinct forms like *Brontosaurus* (Fig. 1), and living forms like tortoises, turtles, lizards, gila monster, chamaeleon, snakes, crocodiles, etc.

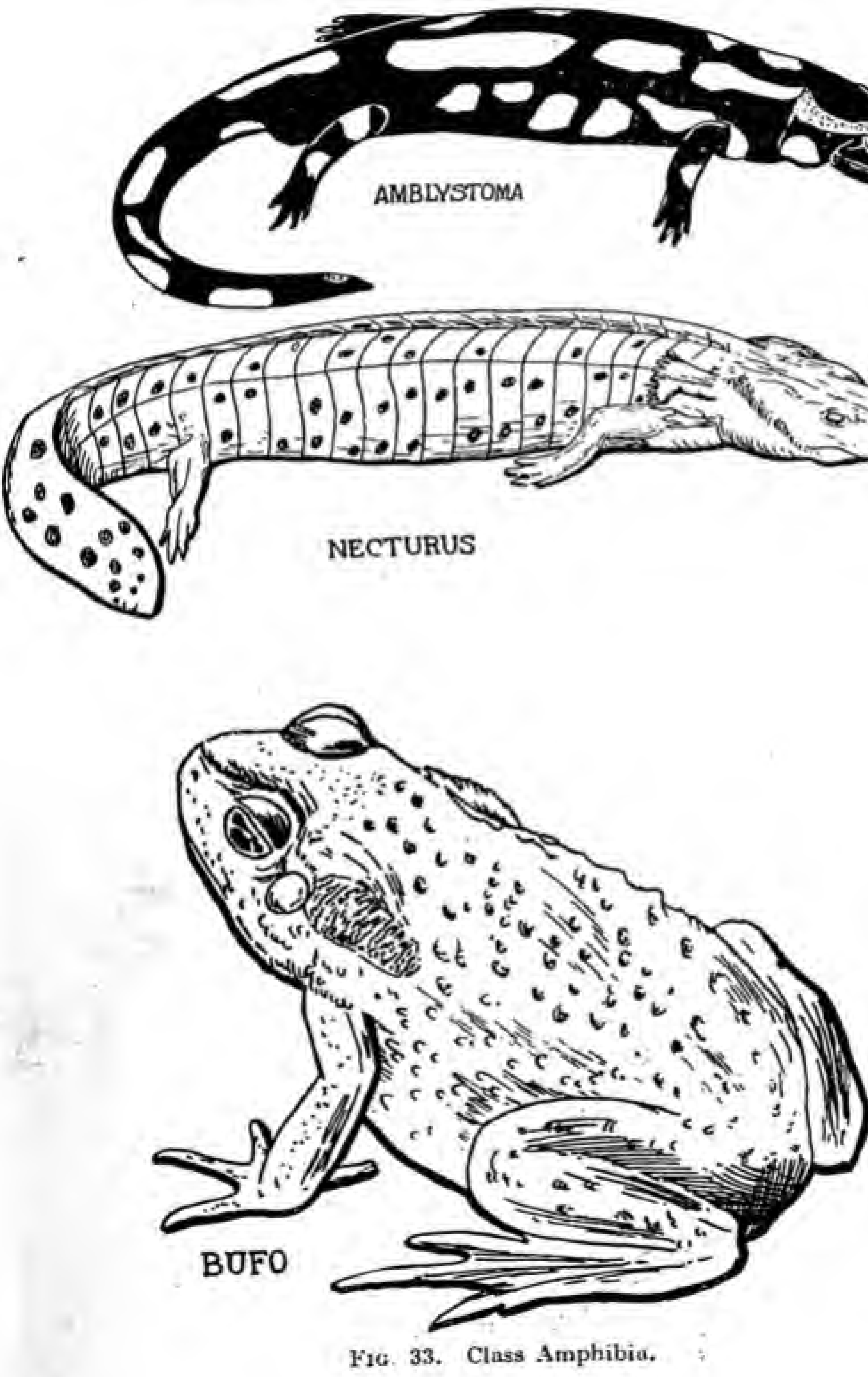


FIG. 33. Class Amphibia.

Fig. 24. Class Reptilia.

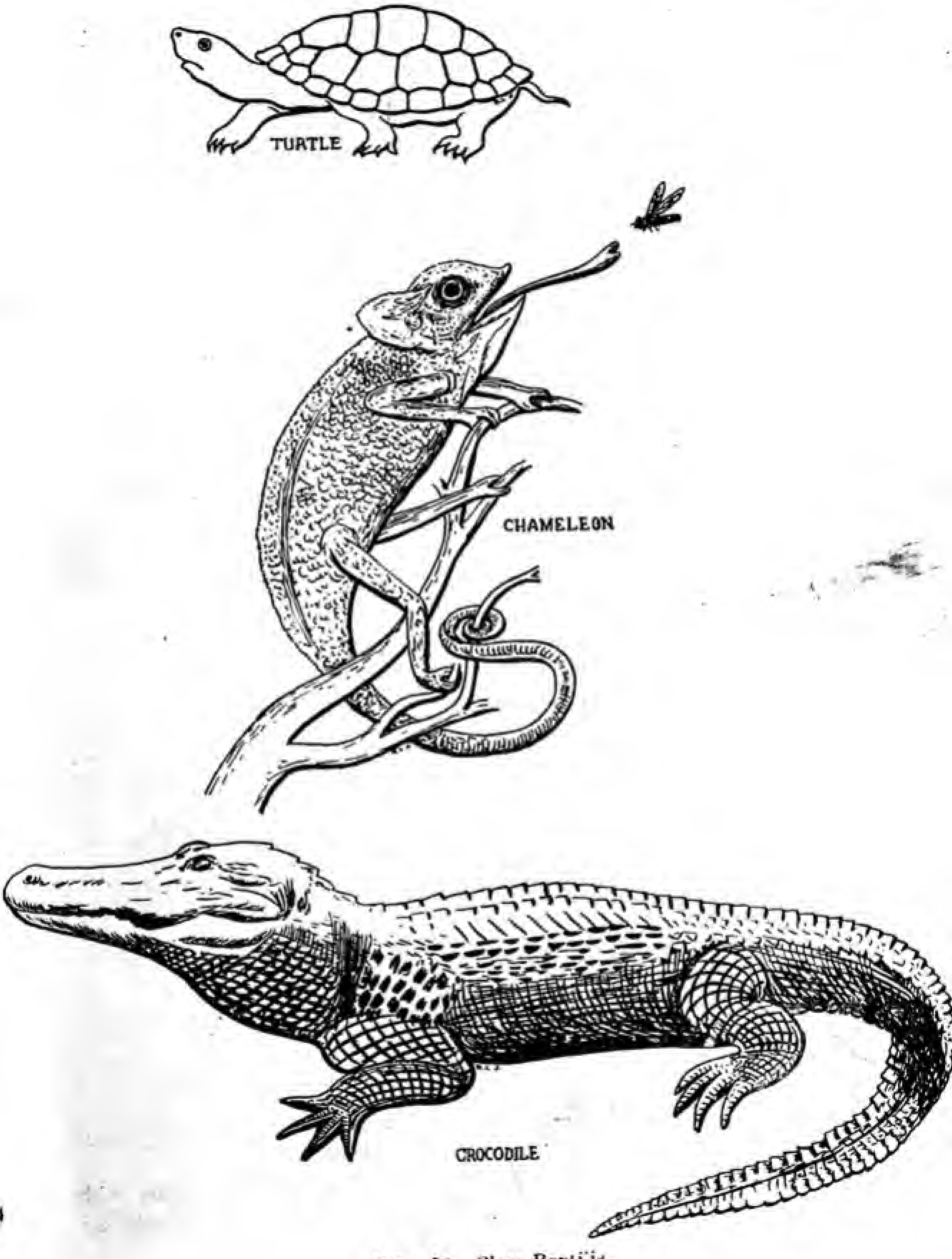


FIG. 35. Class Reptilia.

Class (*iii*) AVES. Birds. (Figs. 37, 38, 39) Feathered bipedal vertebrates, with forelimbs modified into wings. Heart four-chambered, *right* aortic arch alone present. No teeth in modern forms. Body temperature higher than that of any other animal. Examples : Extinct birds like *Archaeopteryx lithographica*,

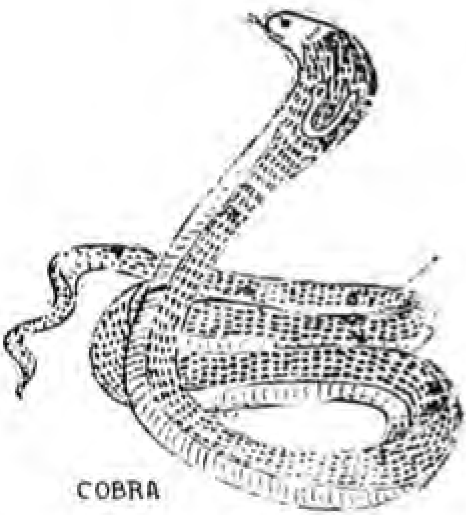


FIG. 36. Class Reptilia.

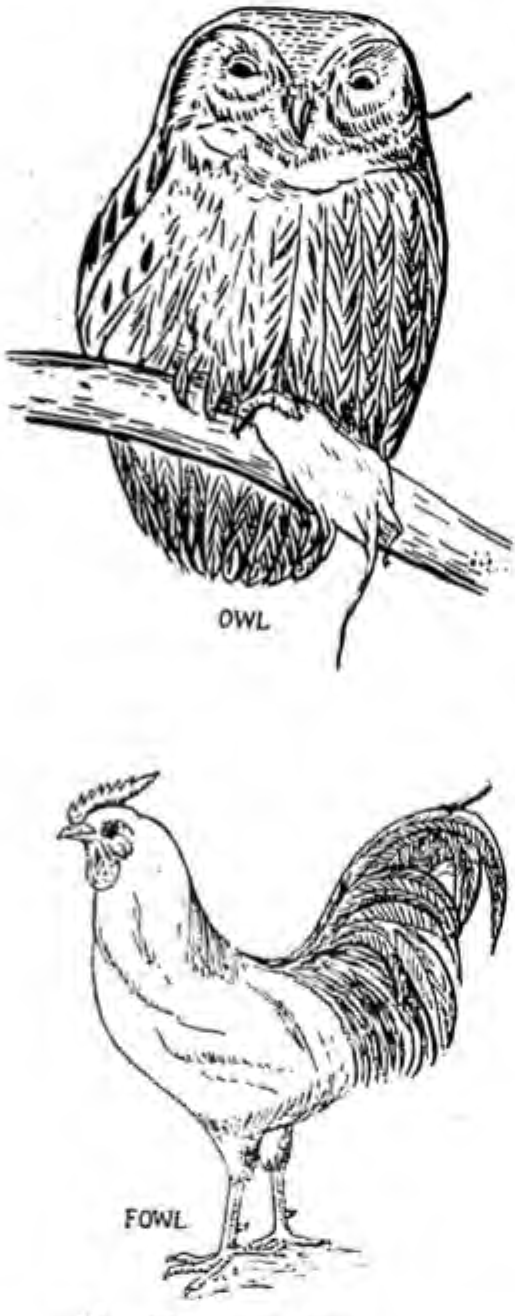


FIG. 37. Class Aves.

ancient toothed birds like *Hesperonis*; ostrich, cassowary, kiwi, crow, pigeon, sparrow, owl, kite, vulture, etc.

Class (*iv*) MAMMALIA. Mammals. (Figs. 40, 45) Tetrapods with hairy covering on the body and mammary glands for

suckling the young. Sweat glands present. Four-chambered heart with only the *left* aortic arch. Teeth modified for different functions. Examples : *Platypus*, *Ornithorhynchus*, kangaroo, opossum, mole, bat, sloth, cat, lion, dog, walrus,

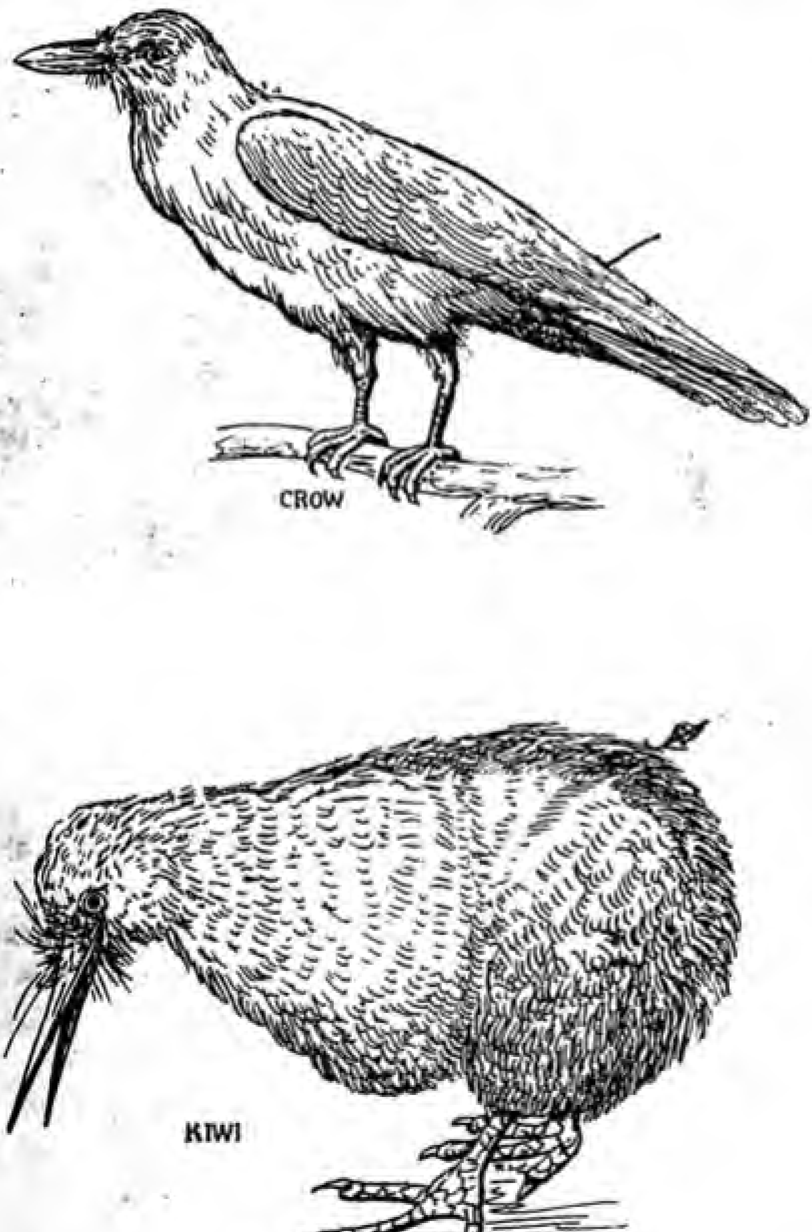


FIG. 38. Class Aves.

whale, elephant, cattle, *Hippopotamus*, giraffe, horse, zebra, *Rhinoceros*, monkey, chimpanzee, man.

In this classification of animals, the phylum Protozoa stands at the bottom of the scheme. It is the simplest of all groups of animals and its members lack tissues or organs. The first animals on the earth were also Protozoa. Gradually in course of time, extending over several hundreds

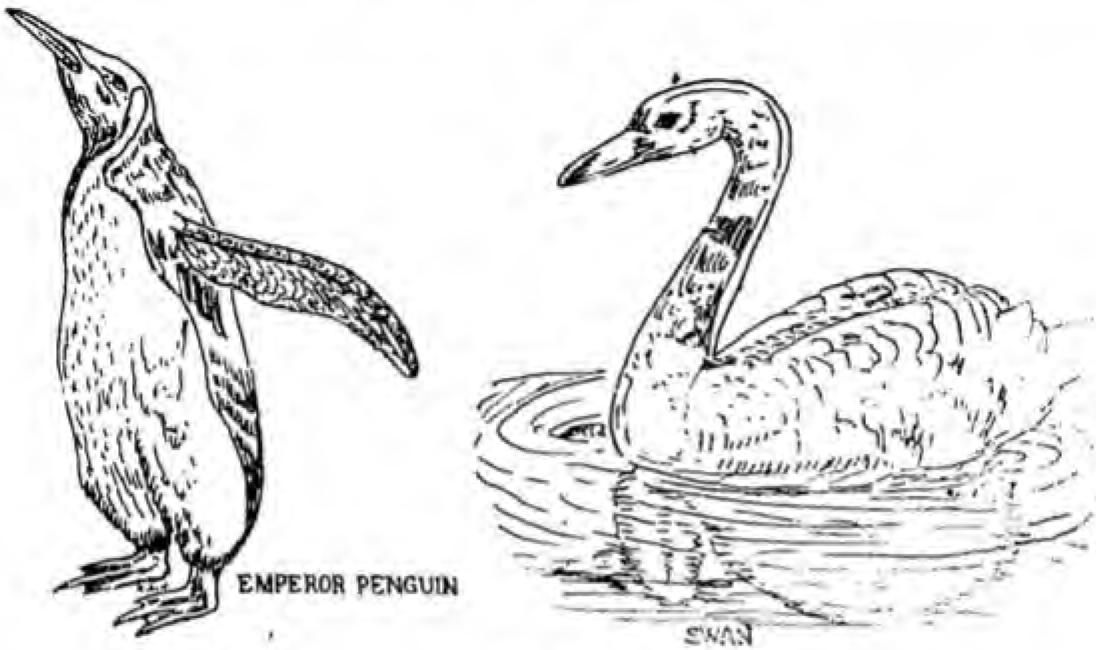


Fig. 30. Class Aves.

of million years, these simple forms came to be associated in colonies, until finally the association became more and more intimate, so that the individuals lost something of their independence They divided their functions : those on the surface looked after defence or locomotion and those in the interior took on the work of nutrition. Thus the multicellular animals were born. These were the Coelenterata, which are therefore placed next in our classification By successive stages they became more and more improved and better adapted for performing the various complicated functions of life and thus gave rise to various phyla like Platyhelminthes, Annelida, Arthropoda, etc. After numerous intermediate stages, the phylum Chordata appears. The Chordata are the most complex and also the most recent of all phyla and are therefore placed at the top of the series.

This classification actually tells us at a glance the story of ***differentiation*** of more and more complex forms of animals out of simple types, or as it is called *evolution*. You will learn further about the absorbing story of evolution in the last chapter of this book.

Scientific Names.—When we wish to speak of any object, we naturally find it necessary to give a name to it and also describe it so that

others can easily recognize what we mean. Animals must therefore have names and they must also be carefully described. The same kind of

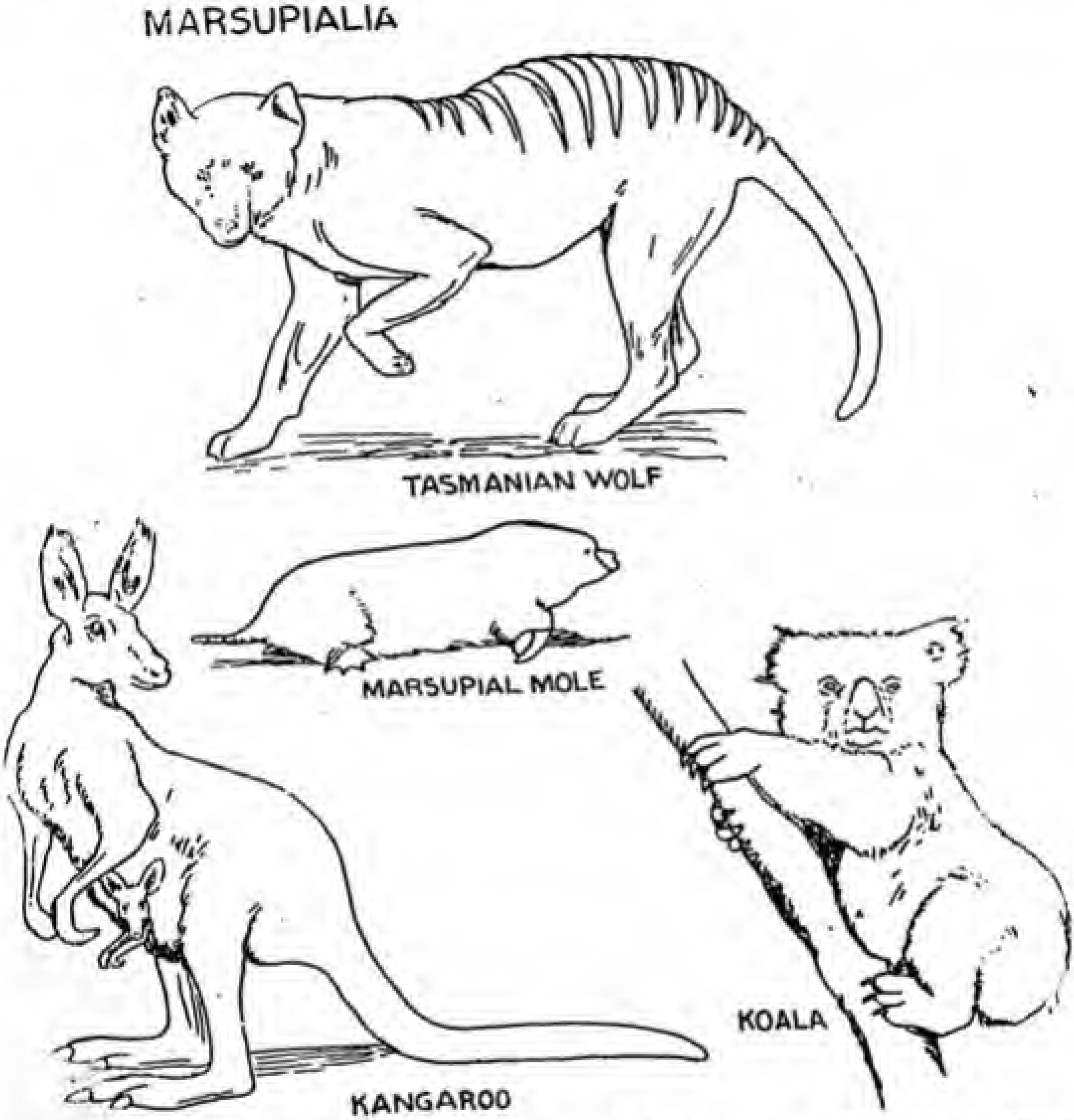


FIG. 40. Class Mammalia. (*By courtesy of the American Museum of Natural History*).

animal often occurs in different countries, where people speak different languages. The result is, an animal comes to have many different names. Very often the same name is also applied to different animals, so that confusion results. As there was however no uniform method in the early days for giving names, each author made lengthy and confused descriptive names, like for example *Limax, cinereus, maximus, striatus et maculatus* for a common slug of Europe!

It is therefore necessary that every species of animal should have a distinctive name, which is *universally* accepted. Common names are

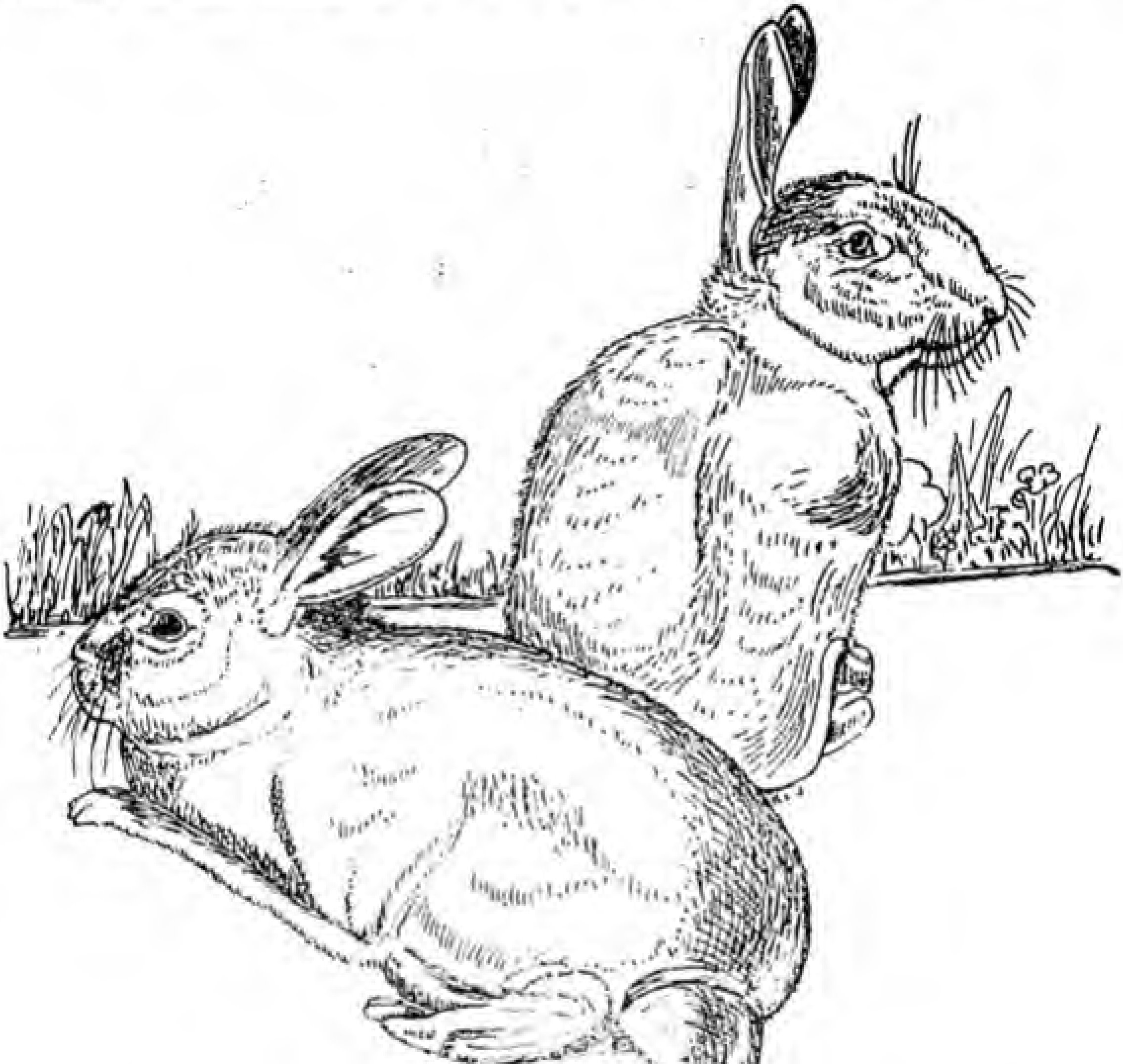


Fig. 41. Class Mammalia.

obviously unsuitable. For this reason each animal bears a ***scientific name*** in Latin, comprising two parts, first the name of the ***genus*** to which the animal belongs, always written with an *initial capital letter* and second the name of the ***species***, always written with an *initial small letter*. For example, the scientific name of the common house crow of India is *Corvus splendens*. The Indian jungle crow belongs to the same genus but is a different species and is known as *Corvus coronoides*. Similarly the domestic cat, tiger, lion and leopard belong to the same genus, viz. *Felis* but constitute different species. Their scientific names are : *Felis domesticus* the domestic cat, *Felis tigris*, the tiger, *Felis leo* the lion and *Felis leopardus* the leopard.

Since every scientific name consists of two parts or two names, *viz.* names of the genus and of the species, this system of naming animals is

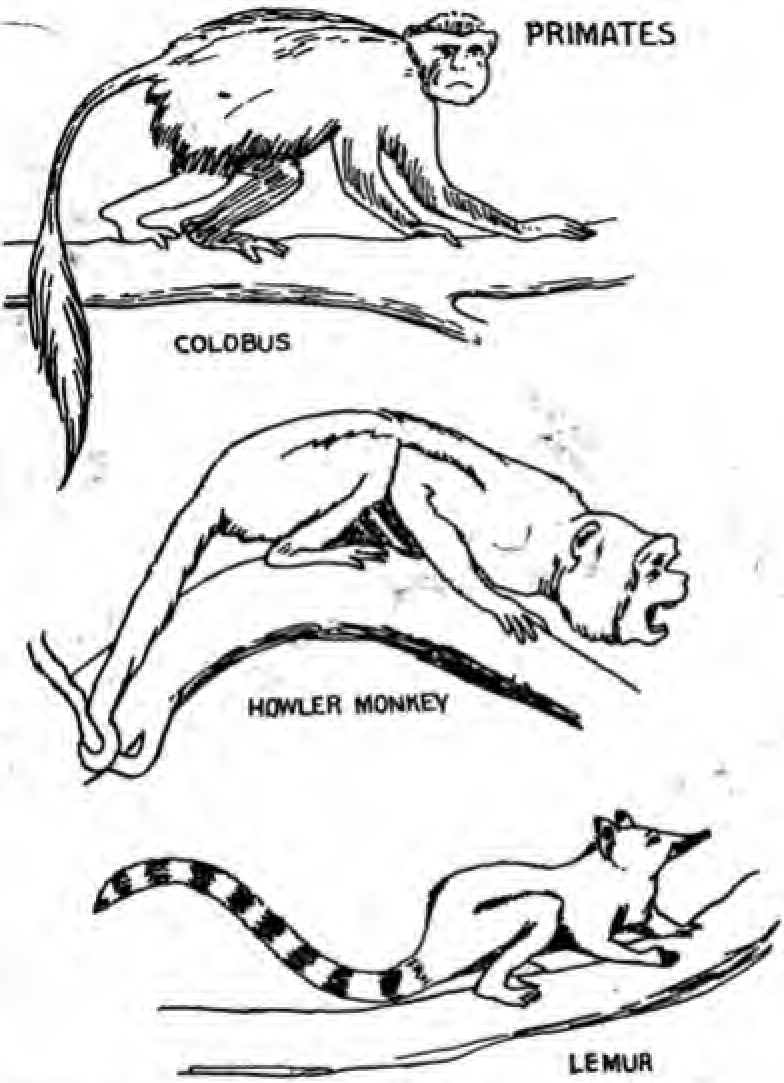


FIG. 42. Class Mammalia. (*By courtesy of the American Museum of Natural History*).

known as ***binomial nomenclature.*** It was invented in 1758 by LINNAEUS (Fig.47) a Swedish naturalist, and is now internationally recognized, so that the scientific name of an animal is the same all over the world, though common names differ. It is usual to add at the end of the scientific name of the animal, the name of the zoologist who gave the animal its name. The name of the domestic cat is written thus *Felis domesticus* Linn., because Linnaeus gave the name. All scientific names should be underlined when written and are printed in *italics*, in order to distinguish them from

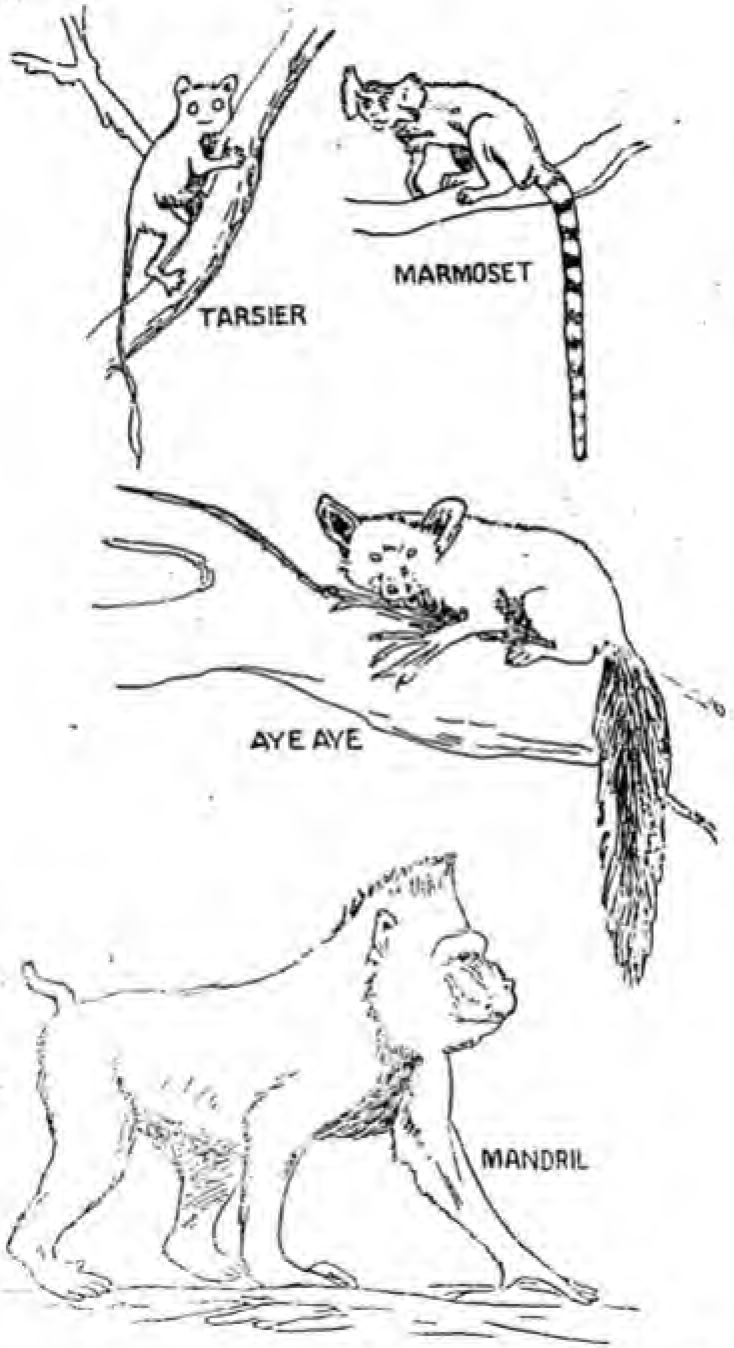


Fig. 43. Class Mammalia. (*By courtesy of the American Museum of Natural History*).

other technical terms. To facilitate naming any newly discovered animal the International Zoological Congress have made certain rules, which are followed all over the world.

FIG. 44. Class Mammalia. (*By courtesy of the American Museum of Natural History*).

The binomial method of naming an animal does much more than merely give a *universally* recognized name to an animal. The scientific name is indeed a kind of shorthand of the zoologist. It tells us at once the affinity of the animal, *i. e.*, it gives us the systematic position of the animal or in other words, its place in our scheme of natural classification. For example, the systematic position of the domestic cat and the crow are given thus :

Kingdom ANIMALIA (Animals)
Phylum CHORDATA—Animals with backbone
Class MAMMALIA—Backboned animals which suckle their young with milk secreted by the mammary gland
Order Carnivora—Flesh-eating animals
Family Felidae (Cat family)
Genus *Felis* (Cats)
Species *domesticus* (house cat)

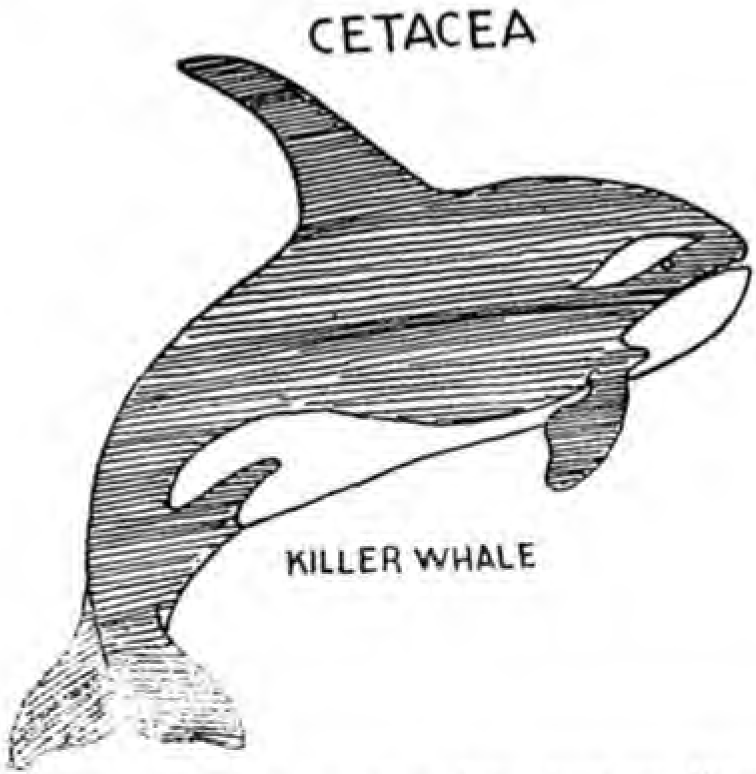


FIG. 45. Class Mammalia. (*By courtesy of the American Museum of Natural History*).

Kingdom ANIMALIA
Phylum CHORDATA
Class AVES (Birds)
Order Passeres (Perching birds)
Family Corvidae (Crows family)
Genus *Corvus* (Crows)
Species *splendens* (The splendid house crow)

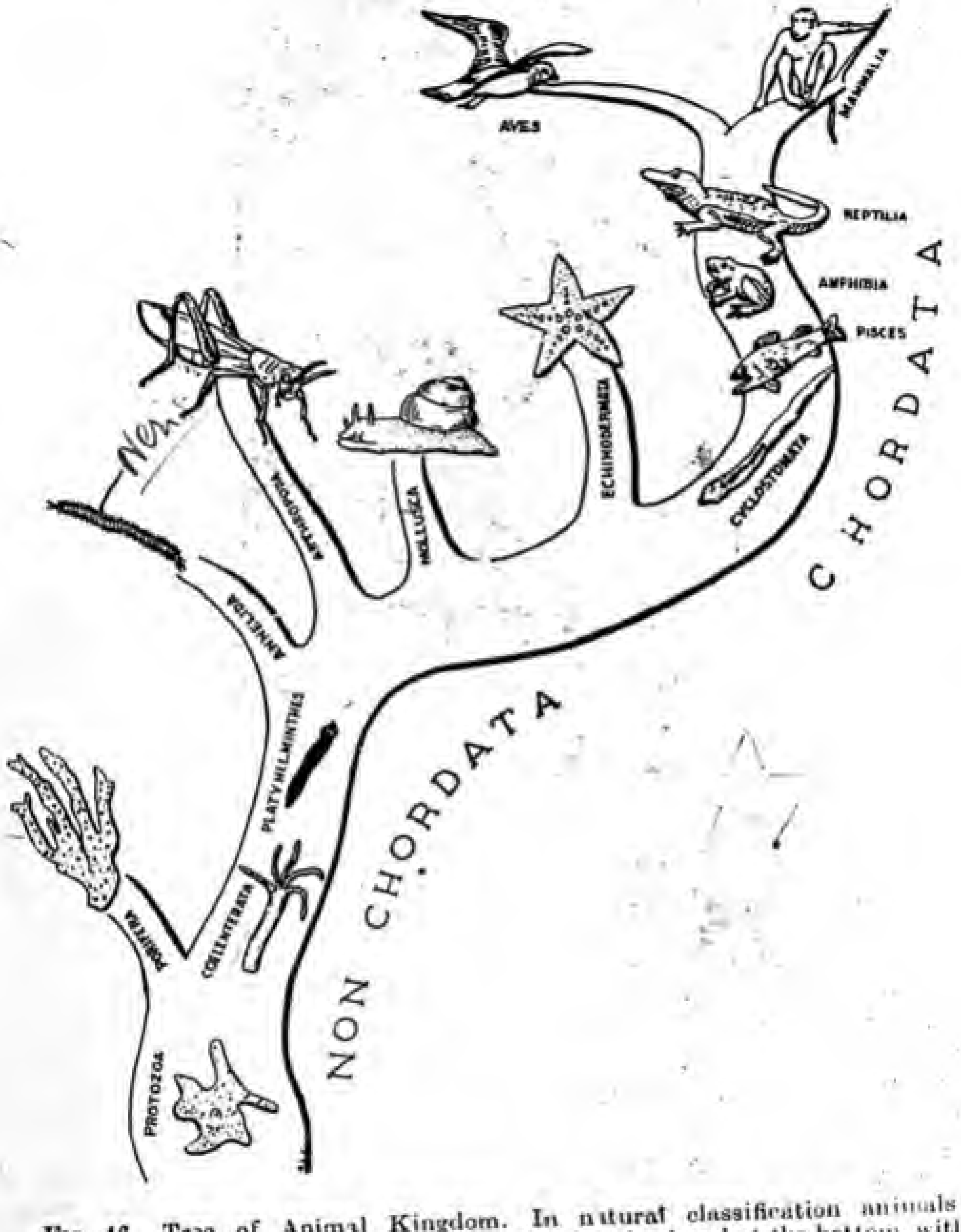


FIG. 46. Tree of Animal Kingdom. In natural classification animals are arranged in a graded series, such that the simplest is placed at the bottom, with the more complex at the top. This sorting out is made on basis of blood-relationship of animals as shown by structural resemblance. Classification is thus no mere cataloguing. It is really finding out the affinities and deciding which came first, which second and so on. It is therefore not an end in itself but only means to end.

FIG. 47. Karl von Linne or Linnaeus, (1707—1778) as he is usually known, a Swedish naturalist, is the father of binomial system of nomenclature of animals. The twelfth edition of his *Systema Naturae* published in 1757 is the starting point of the modern science of taxonomy.

RESUMÉ

1. Classification brings order out of chaos.

2. Classification is sorting out and arranging animals according to their blood-relationships in a graded series of groups, with the simplest and the most ancient at the bottom and the youngest and most complex at the top.

3. Animals are divided into a number of phyla, the phyla are subdivided into classes, classes into orders, orders into families, families into genera and genera into species.

4. A natural classification aims at presenting the story of evolution of animals in a condensed form.

5. The scientific name of animals is formed by the name of the genus and the name of the species. The system is therefore called binomial nomenclature. Scientific names of animals are the same all over the world.

CHAPTER III

THE FROG AS A TYPE OF ANIMAL

1. BIONOMICS AND SYSTEMATIC POSITION

Bionomics.—All of you must be familiar with frogs. They are quite common during the rains. They live in water or in moist places on land. Hence they are called ***amphibious*** (*amphi*=both, *bios*=life) animals.

Different species of frogs live in different kinds of surroundings or ***habitats***. Several of them live in pools, others in streams and still others in marshes. Many live on trees and some can even burrow underground to nearly a foot and a half. Frogs are however never found in the dry deserts or in the sea.

During summer, when the ponds and streams are likely to be dried up, the frogs bury themselves in the muddy bottoms of their ponds, where they remain in a torpid state and are said to ***æstivate***. In cold countries, frogs remain dormant during winter, when they are said to ***hibernate***. With the onset of rains they again come in thousands and the males sing in glee all night long. You then hear the familiar chorus of ***croaking*** of frogs. The males are very quarrelsome and they often fight among themselves.

Frogs feed on flies and other small insects, worms, snails and even other smaller frogs. Some of them devour small fish or birds. They are perfectly harmless to man but have numerous ***natural enemies***. For example, snakes, turtles, herons, cranes, storks, racoons and men take a heavy toll of frogs. The only means of defence for the frog against its numerous enemies is escape by diving under water and hiding beneath stones and other debris. They are also attacked by many internal parasites like worms.

Frogs are really very useful creatures. Considering the number of injurious insects they destroy, frogs are extremely beneficial to agriculture. Frogs are also eaten in many countries like China, Japan, France, and America. Canned frog meat is considered a delicacy in many parts of America. Thousands of frogs are sacrificed in various scientific investigations. Important discoveries in physiology have been made from experiments on frogs. We are indebted to the frogs again for much of our knowledge of the spinal cord, the excitability of nerves and of the circulation of blood in

capillaries. Frogs are dissected in many thousands by biology students all over the world.

Systematic position.—Frogs belong to the class Amphibia (=Batrachia), phylum Chordata. Amphibians are quite at home in water or on land. They begin their life as completely aquatic ***tadpoles***, without legs or lungs and breathing by means of gills, exactly like fishes. The temperature of their blood is not constant as in our case but varies with that of the surroundings and is usually that of the water in which they normally live. They are therefore cold to our touch and are called ***cold-blooded*** animals. Amphibia lie on the borderland between the fish (with fins and gills for aquatic life) and the reptiles (with limbs and lungs for terrestrial life).

There are nearly three hundred species of frogs in the world. They belong to a number of different genera and families. In India, for example, there are nearly a dozen genera of frogs, containing nearly fifty species. The largest and the most widely distributed of the Indian species of frogs is scientifically known as *Rana tigrina* Daud., or the tiger-marked green or olive-coloured frog, with dark spots. It is found all over India, Ceylon, China and Malaya and usually lives in ponds and tanks. *Rana hexadactyla* Lesson is another similar but somewhat smaller common frog in this country. *R. limnocharis* Wiegm. and *R. cyanophlyctis* Schneid are other more or less common Indian species. *R. breviceps* is a fossorial species capable of burrowing underground. Frogs belonging to the genera *Rhacophorus* and *Hyla* are scansorial and can climb trees. Toads, which differ from frogs largely in their warty skin, belong to another family Bufonidae. The commonest Indian toad is *Bufo melanostictus*.

The systematic position of *Rana tigrina* and other common frogs and toads is as below :

Kingdom ANIMALIA (animals)
  Subkingdom M E T A Z O A (multicellular animals)
    Division ENTOZOA (with gut)
      Phylum *CHORDATA* (with notochord)
        Section C r a n i a t a (with cranium or brain case)
          Subphylum G n a t h o s t o m a t a (with jaws)
            Superclass Tetrapoda (with four limbs)
              Class A m p h i b i a (living both in water and on land)
                Order A n u r a (without tail)
                  Family 1. Ranidae (frogs)
                    Genus *Rana*

Species *tigrina* Daud. (tiger-spotted frog)
Species *hexadactyla* Less.
Species *cyanophlyctis* Schneid.
Species *breviceps* Schneid.
Species *limnocharis* Wiegm.

European species :—

Species *temporaria* Linn. (green frog)
Species *esculenta* Linn. (edible frog)
Species *oxyrhinus* St.
Species *pipiens* (leopard frog)
Species *catesbeiana* (bull frog)

Family 2. Hylidae
Genus *Hyla*
Species *annectens* (Jerdon)

Family 3. Polypedatidae
Genus *Rhacophorus*
Species *maculatus* (Gray) chunam frog

Family 4. Bufonidae
Genus *Bufo*
Species *melanostictus* Schneid. Common toads

Family 5. Pipidae
Genus *Pipa* (tongueless toad)
Species *pipa* (Surinam toad which carries her eggs on the back).

2 EXTERNAL FEATURES OF FROG

In a frog belonging to any of the common species mentioned above, the following ***external features*** may be observed without dissection of the animal. The body of the frog is short and flattened from above downwards or ***depressed***. It is somewhat bluntly pointed in front and broadly rounded behind. The body comprises a ***head*** and a ***trunk***. There is no neck, the head being broadly attached to the trunk. There is no tail.

The frog always moves with the head forwards; this end is called ***anterior*** end and the opposite end is ***posterior***. There is an upper or ***dorsal*** surface and an under or ***ventral*** surface. There are two pairs of limbs attached on either side. *viz*. the right and left sides of the body. The two sides are identical and equally large and therefore the body of the frog is ***bilaterally symmetrical***. Structures on the ***longitudinal axis*** of the body are called ***medial*** or ***median*** and those towards the sides are called ***lateral***.

The colour of the common Indian frog is usually green, olive or brown. The body is also often spotted or mottled above. The dorsal surface is more deeply coloured than the ventral surface. Frogs have the power of changing the colour of their body. The tree frog *Hyla*, (Fig. 48) for example, is capable of rapidly changing its colour to match

HYLA

Fig. 48. *Hyla* the common tree frog is capable of rapidly changing its colour to match the background and thus become inconspicious to its enemies. Its peculiar fingers and toes help in climbing tree.

the background and thus become perfectly inconspicuous or invisible to its enemy. The colour of frogs is due to certain pigments in their skin. The green colour is however due to the blending of the blue rays refracted by the ***guanin*** granules with the yellow of oil droplets in the skin.

A frog is very slippery like a fish and it is therefore difficult to hold it in the hand. The skin is smooth, moist and slimy, giving the slipperiness to the frog. It is loosely attached to the parts beneath by subcutaneous connective tissue and the space underneath is filled with a pale liquid called ***lymph***. The skin contains ***glands***, which secrete the slimy ***mucus*** on the surface. The mucus keeps the surface of the skin moist, aids escape of the frog from its enemies by making the body slippery and reduces the friction with water in swimming. It is also useful as an antiseptic and prevents the growth of germs in the skin.

The skin is really a flexible covering for the vital parts inside. It provides protection to the internal organs. A frog never drinks water but absorbs all the water it requires through its skin. A frog also breathes a great deal through its skin when on land and exclusively when under water. The skin also contains a few poison glands, which produce a whitish

acrid alkaliod and thus help the frog in escaping from the enemy. The frog differs from fishes, snakes, lizards, birds, man and other beasts in not having scales, feathers, hairs, claws or nails.

The head of the frog (Fig. 49) is subtriangular in outline, with the broad base behind and round apex or ***snout*** in front. On either side of the head is an ***eye***. The eyes bulge prominently above the surface to enable

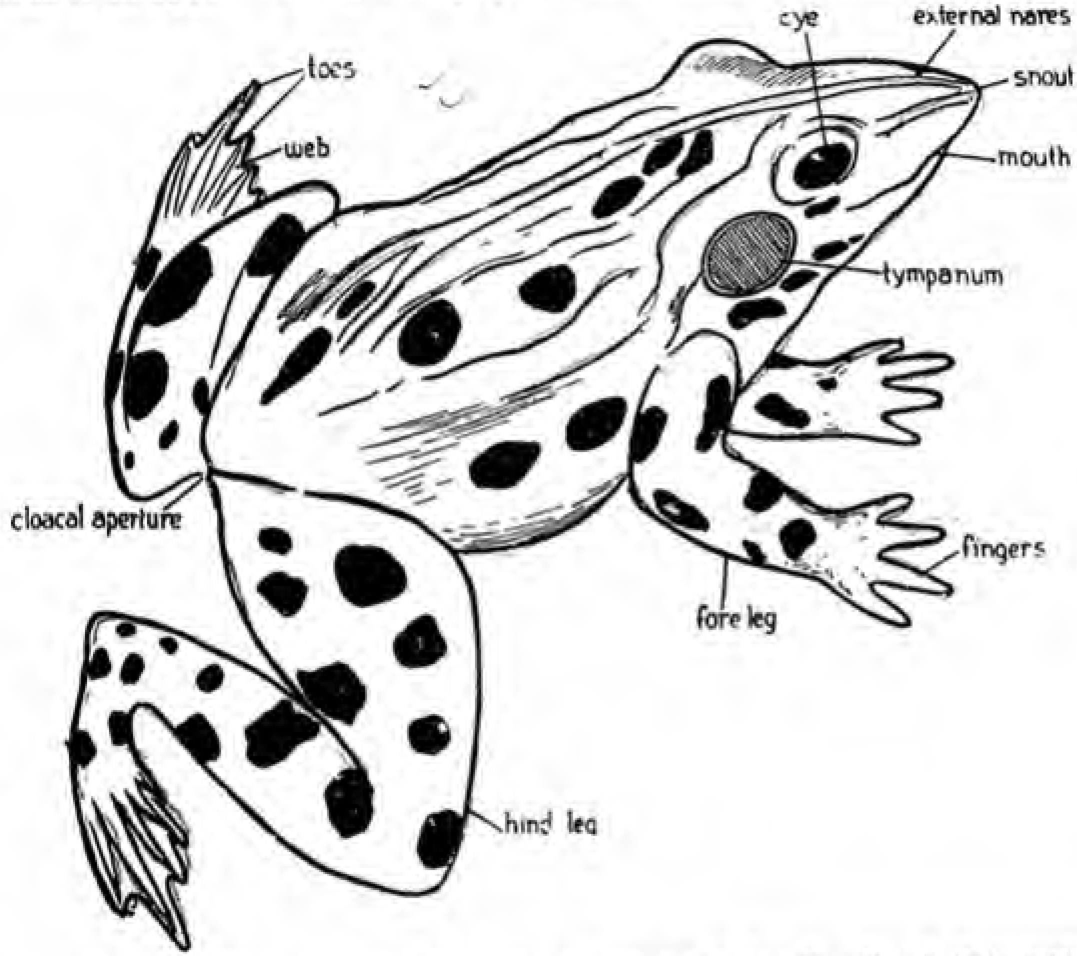


FIG. 49. Frog. External features. A frog is well fitted to live both in water and on land.

the frog to see all round, because, not having a neck, it is incapable of turning the head in the direction it wants to see. The eyes can be withdrawn into their sockets and closed. There is a prominent and immovable upper eyelid in the form of a thick fold of skin. The lower eyelid can move up and cover the eye but this does not really correspond to the lower eyelid of ourselves. It is a third eyelid called ***nictitating membrane***, represented in man as a small fold in the corner of the eye next to the nose. A nictitating membrane similar to that of the frog occurs in crocodiles and birds also. Eyebrows and eyelashes are absent in the frog.

Behind the eye there is a tightly stretched dark grey membrane as a pair of circular patches bounded by a firm raised ring. This is the eardrum or ***tympanic membrane***. The frog has no lobe or ***pinna*** of the ear as in the dog or man. There is also no tubular passage leading down to the eardrum; the latter is on the surface of the body itself. Between the eyes can be seen a ***brow spot***, which marks the position of a vestigial median eye called the ***pineal body*** or ***pineal eye***, which was present in the ancestors of the frog and some reptiles.

There is a wide gaping, transverse, slit-like mouth in the anterior end of the head, bounded by horny lips. At the posterior end of the trunk lies the ***cloacal aperture***, between the two hindlegs. Through this opening faeces, urine and eggs or sperms are shed and it is therefore differently named from the anus of higher animals, through which only faeces is passed. On the dorsal surface of the head there is a pair of small circular holes near the anterior end. These are the ***anterior*** or ***external nares*** or nostrils, which lead into the respiratory and olfactory passages, the *nasal cavity*.

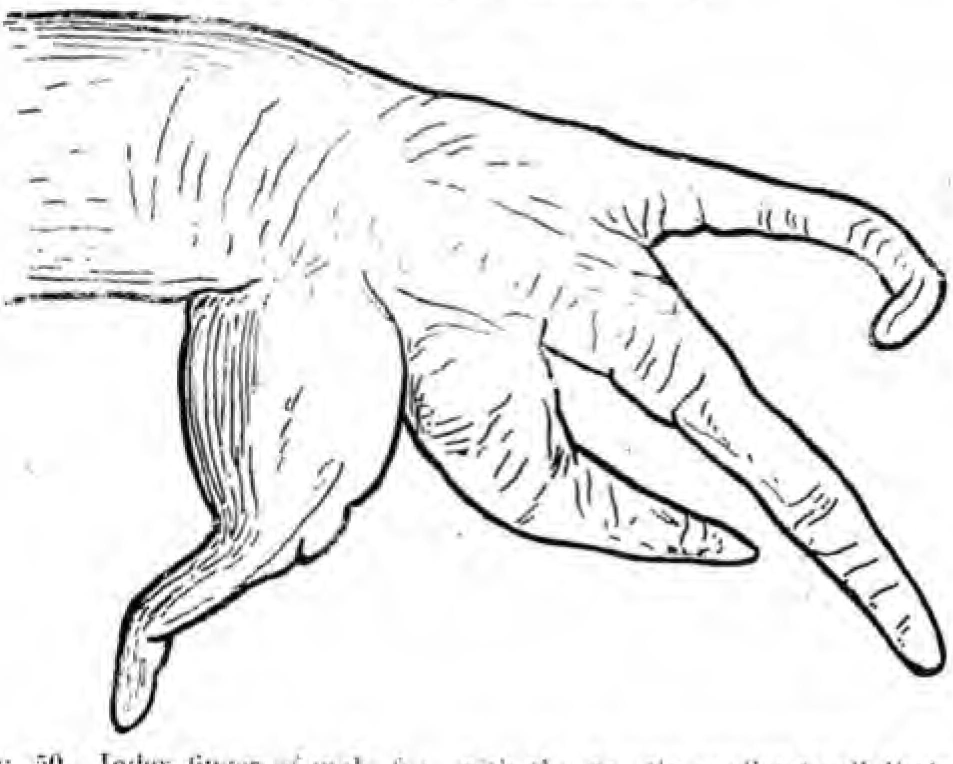


FIG. 50. Index finger of male frog with the greatly swollen 'pad' distinguishes him from the female frog.

The four limbs correspond to our own. The anterior pair or ***forelegs*** are shorter and more slender than the posterior pair or ***hindlegs***. The foreleg is divisible into an upper arm, the ***brachium***,

a lower arm or ***antebrachium*** and hand or ***manus*** The ***carpus*** or wrist is inconspicuous. There are four digits or ***fingers***, corresponding to the four fingers of our own hand. The thumb is rudimentary and hidden under the skin. Counting from the thumb, the five digits are called respectively the ***pollex***, ***index***, ***medius***, ***annularis*** and ***minimus***.

The hindlegs are longer, stouter and stronger than the forelegs, as an adaptation for the jumping habit of the frog. The hindleg consists of the upper leg called thigh or ***femur***, the lower leg called shin or ***tibia***, ankle or ***tarsus*** and the long foot with a narrow sole ***metatarsus*** and five slender digits or ***toes***. Close inspection reveals the presence of sixth rudimentary toe. Of the five digits the fourth is the longest in both the fore and hindlegs. The digits of the foreleg are free but the toes of the hindlegs are united by a thin, translucent, ***interdigital membrane*** or ***web***. Webbed toes are used as oars in swimming and are found not only in the frog but also in other similar swimming animals like the duck. The part of the leg near the body is termed ***proximal*** and the part away from the body is termed ***distal***. Thus the femur is the proximal part and the tarsus is the distal part of hindleg.

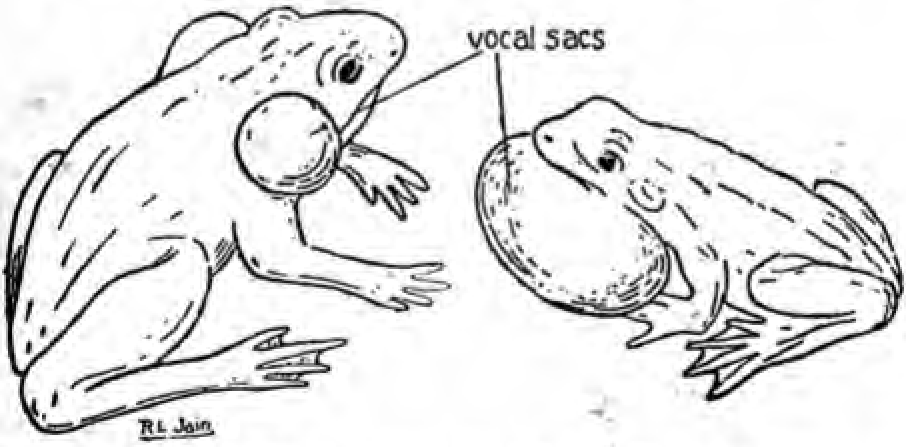


FIG. 51. Male frogs with their vocal sacs inflated These sacs contain resonating air and thus enormously amplify the frog's nocturnal music.

When on land the frog rests with its forelegs nearly upright and the hindlegs turned forwards and flexed beside the body. When disturbed, the frog jerks off the powerful hindlegs, leaps into the air and again lands on the ground at some distance. It is said to ***hop***. Hopping is the general mode of locomotion of the frog on land. Under water, it can dive deep and swim below the surface with the

help of the webbed hindlegs, which are alternately extended and flexed, the web being used as oars. A frog can also float just below the surface of water with only its external nostrils and the bulging eyes in the air.

The male frog is easily separated from the female frog during the breeding season. At this time the belly of the female frog is distended with her eggs while that of the male is slender. The index finger of the male frog develops a thick cushion-like swelling or pad. On either side of the throat there is a pair of loose fold of skin, which encloses the resonating ***vocal sacs*** in the male frog (Fig. 51) The vocal sacs are inflated and filled with vibrating air when the male is croaking at night. These sacs serve to increase the volume of the sound produced.

Although a frog is capable of living both in water and on land, it is not completely emancipated from the former medium. A frog has to return to the water for breeding, because its eggs will not develop on land. Further, prolonged stay on land is fatal to a frog. Frogs which enter warm dry rooms at night are found dead and shrunk to half their size next morning, because of the evaporation of water from their body during the night. A frog cannot therefore wander far away from the neighbourhood of water.

It is well equipped for living in water. Unlike a land animal, an aquatic animal is freed from the burden of supporting the weight of its body due to the buoyancy of water. It is therefore advantageous for an aquatic animal to have flat body so as to increase the buoyancy. The powerful legs of the frog, with their webbed toes, help in swimming in water. The posterior end of the body of frog is heavier than the anterior, so that the frog can float without effort under the surface of water with just its nostrils and eyes above. This is very necessary, because not only must a frog perceive the approach of an enemy from above, but it must also breathe the air Although a frog can breathe through its skin when under water, the oxygen obtained in this way is not adequate and it will die if it cannot rise to the surface occasionally to breathe the air directly. A frog is thus incapable of living wholly under water like a fish, or entirely on land like a reptile, bird or beast. Its body is built in such a way that it can jump from water on to the land or from the latter back to water if need be. It is thus ***adapted*** for amphibious life. The amphibious ***adaptations*** of the frog are :

For life in water

1. Depressed body
2. Heavier posterior end
3. Respiration through skin
4. Slimy skin
5. High position of the external nostrils and of the bulging eyes
6. Power of closing the external nostrils tightly to prevent entry of water
7. Webbed toes

For life on land

1. Presence of four legs
2. Bulging eyes aiding all-round vision, because the head cannot turn about
3. Long powerful saltatory (jumping) hindlegs
4. Moist and slimy skin to retard evaporation of water from the surface of the body
5. Ear to detect vibrations in air (sound)
6. Ability to aestivate and hibernate during unfavourable weather
7. Nose cavity connected with mouth cavity and used not merely for smelling but also for breathing air
8. Presence of nictitating membrane in the eyes

3. ORGAN SYSTEMS AND THEIR FUNCTIONS

The body of a frog consists of several different organs, which perform different functions, e.g. the mouth, stomach, heart, brain, eyes, etc. Several organs are specialized in structure and are adapted for a particular kind of function, like nutrition. These constitute an ***organ system***. The following organ systems are found in the frog :—

1. ***Alimentary system*** whose function is taking food, digestion and absorption of food.
2. ***Circulatory system*** serves to distribute the material absorbed by the alimentary system. It also carries the oxygen and helps removal of waste products of metabolism.
3. ***Respiratory system*** supplies the oxygen required by the body.
4. ***Excretory system*** removes the waste products of metabolism.
5. ***Nervous system*** co-ordinates the functions of all systems of the frog and helps the frog to perceive the outside world and properly respond to external stimuli.

6. ***Reproductive system*** is connected with the reproduction of the frog.

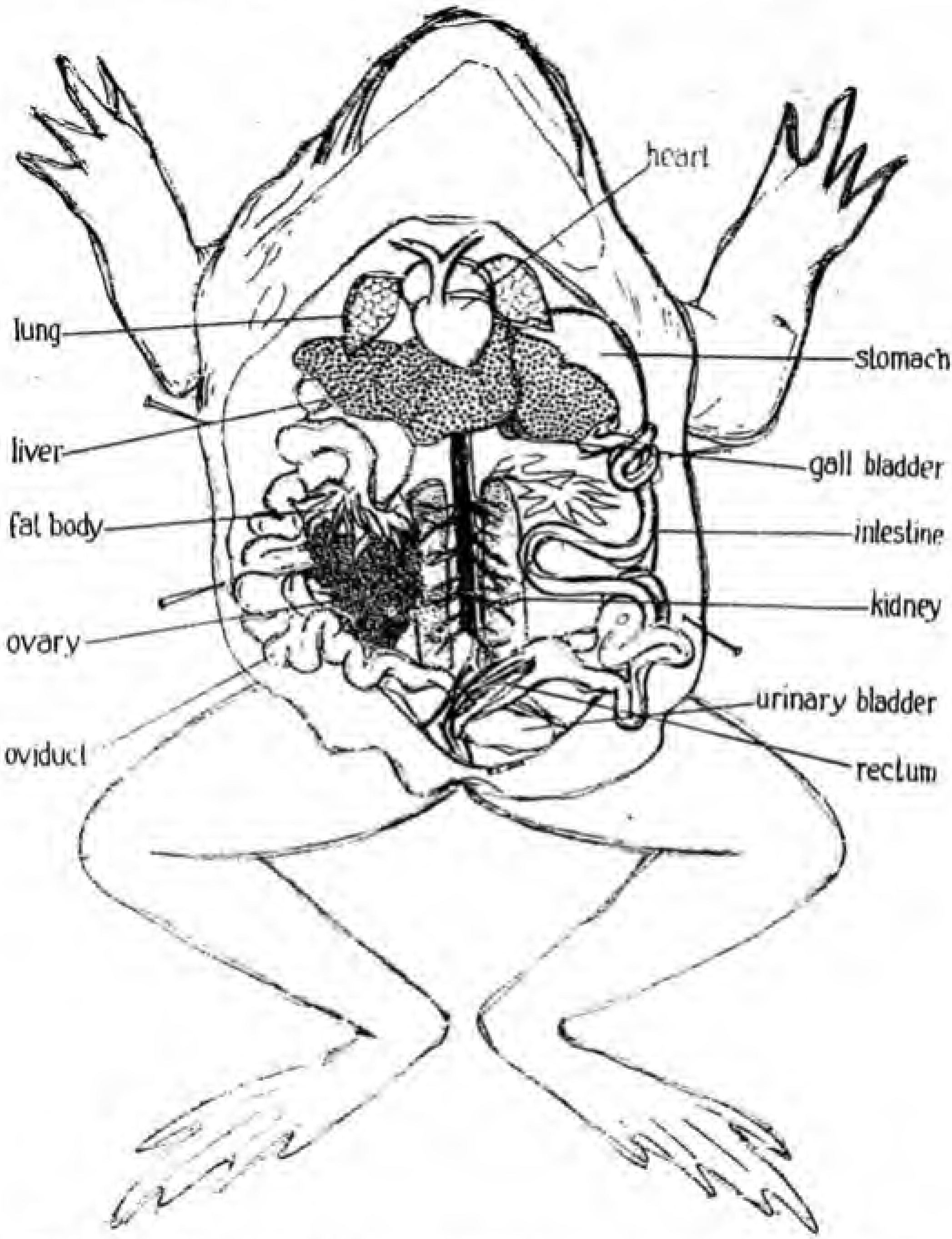


Fig. 52. Frog with its viscera exposed to show some of the important internal organs.

7. ***Endocrine system*** comprises the ductless glands, which regulate the personality of the frog.
8. ***Skeletal system*** gives support to and protects other organ systems. It forms the "frame-work" of the animal.
9. ***Muscular system*** brings about the movements of the body.

These organ systems can only be studied by cutting open the body of the frog. The organs thus exposed by dissection comprise the ***viscera*** (Fig. 52).

4. ALIMENTARY SYSTEM

You learnt in the first chapter that continuous production of energy in living things is brought about by the decomposition and destruction of the complex living substances, resulting in loss of material. This loss is made good by the taking in of food, i.e., ***ingestion***. Since the food of animals consists of either plants or other animals, it is of a complex nature and includes insoluble or non-diffusible carbohydrates, fats or large protein molecules. Before these can be taken into the blood, they must be broken down into simpler soluble or diffusible substances or in other words ***digested***. The products of ***digestion*** are then absorbed or ***assimilated***. The undigested and indigestible matter left over has to be thrown out by ***egestion***. These four processes of ***ingestion, digestion, assimilation*** and ***egestion*** constitute ***alimentation*** (from *alimentum*=nutrition) and are performed by a special organ system called ***alimentary system***.

The body of an animal is essentially a double tube (Fig. 54). The outer tube is the outer body wall and the inner tube represents the alimentary canal. In most Metazoan animals, especially the Chordata the alimentary system consists of two sets of organs, viz. the ***alimentary canal*** (also called digestive tube, gut or enteron) and the ***accessory digestive glands***. The alimentary canal performs the function of ingestion, digestion, assimilation and egestion. The accessory digestive glands help the alimentary canal in the digestion of the food.

Alimentary canal

The alimentary canal (Fig. 54) of the frog is essentially a muscular tube extending from the mouth to the cloacal opening. It is considerably longer than the body of the frog and is therefore coiled. It is not also of uniform thickness everywhere : at some places it is enlarged and at others it is narrowed, so that different distinct regions or parts can be recognized in it. The parts of the alimentary canal of the frog are the buccal cavity, oesophagus, stomach, small intestine, large intestine and cloaca.

The mouth is a wide opening extending backwards as far as the tympanic membrane. It is bounded by the two jaws. The upper jaw is an anterior extension of the head and is therefore not independently movable. The lower jaw is hinged on the posterior part of the head and can be moved up and down, closing or opening the mouth. On the

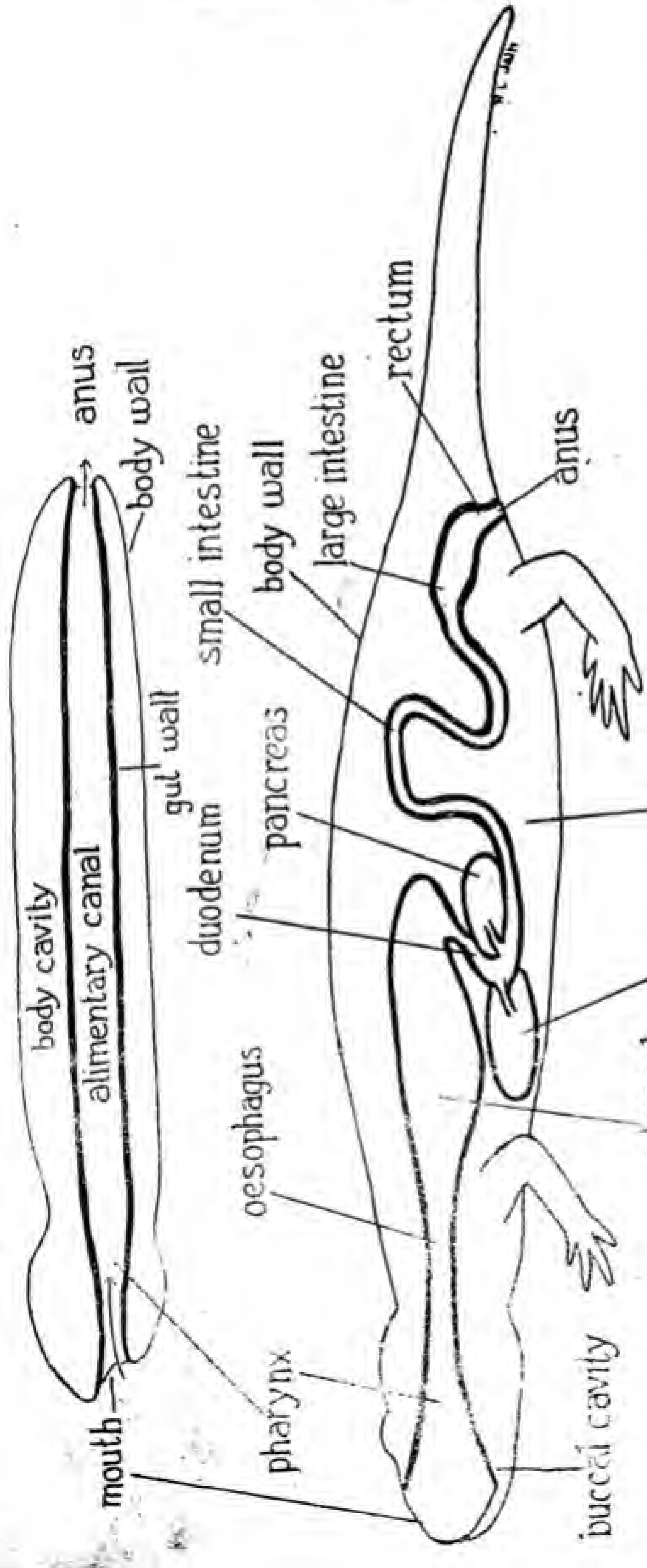


FIG. 53. The body of an animal is essentially a double tube: one tube within another. The outer tube is the body wall. The inner tube is the alimentary canal, that is modified differently in different regions.

upper jaw there is a single row of simple, cone-shaped similar teeth, bordering the mouth. The teeth point backwards and are far more numerous than those of man. The frog's teeth are also not implanted

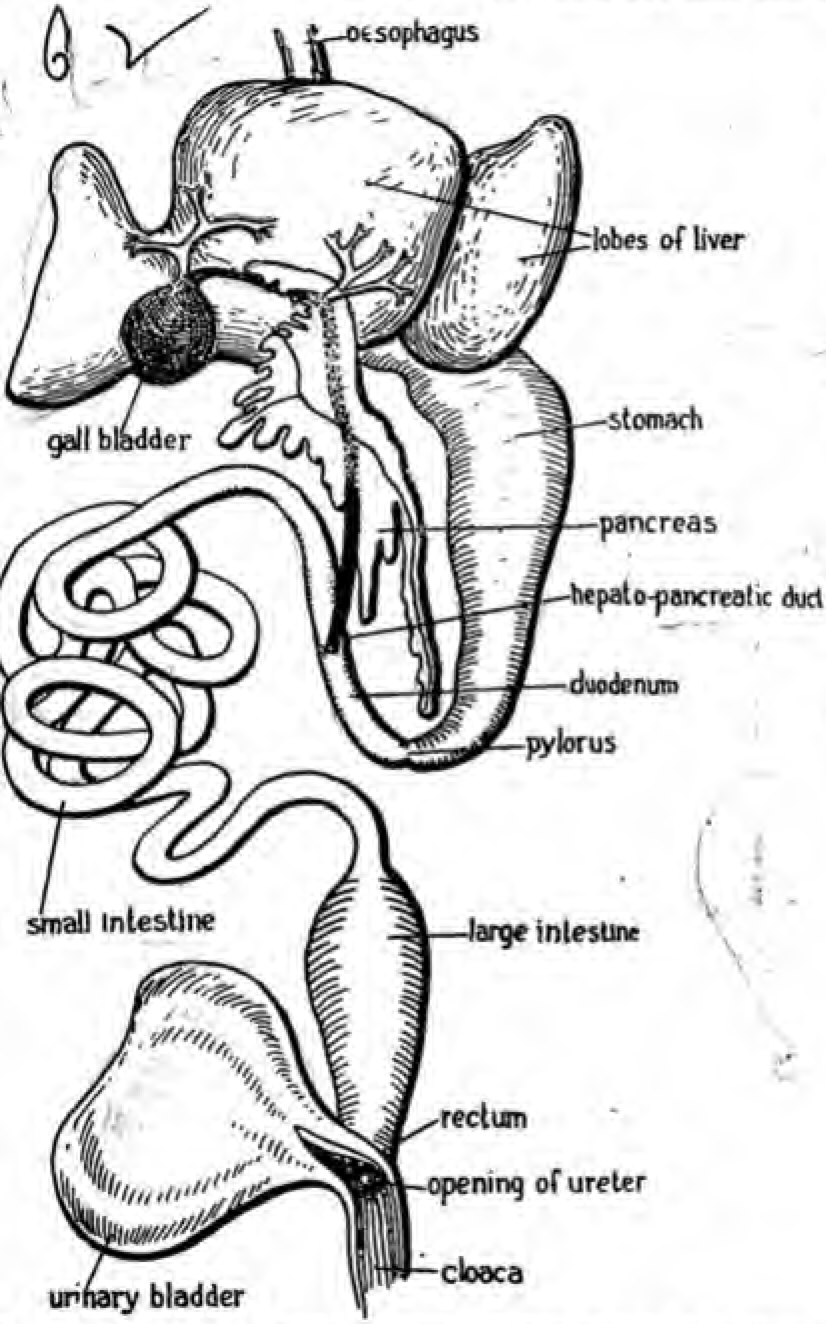


FIG. 54. Alimentary canal and accessory digestive glands of the frog.

in sockets as in ourselves. There are no teeth on the lower jaw of the frog. The toads, which look very much like frogs, do not have teeth on any of the jaws. The skin in the upper jaw projects down like a lip and hides the row of teeth.

The mouth cavity.—(Fig. 55) The mouth leads into a spacious mouth cavity, called also the ***buccal*** or ***oral cavity***. It is lined by mucous membrane. The buccal cavity has a roof and a floor. On the roof of the buccal cavity there is a pair of small patches of the ***vomerine teeth*** anteriorly. The vomerine teeth do not occur in man.

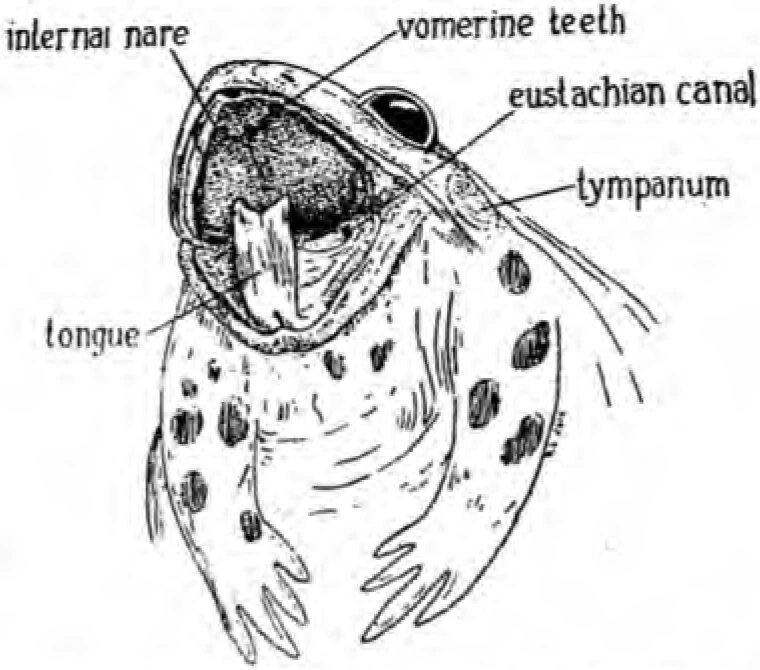


FIG. 55. Frog with its mouth open to show the peculiar tongue. It is attached in front and projects backward into the buccal cavity and can be completely thrust out with lightning-like speed.

Tongue.—The tongue is the most conspicuous structure within the mouth of the frog. It lies on the floor of the buccal cavity and is peculiar in several respects. It is a broad, fleshy, somewhat forked and sticky flap attached to the anterior part of the floor of the cavity and projecting backwards. The tongue of the frog is thus different from that of man ; in man the tongue is attached to the back part of the buccal cavity and its free end projects forwards. The frog can thrust its tongue out of its month with lightning-like speed. Any insect or other moving object is snapped up by its sticky surface. The tongue is then withdrawn into the mouth with the insect (Fig. 56).

Openings in the buccal cavity.—On either side of the vomerine teeth, is the ***internal*** or the ***posterior nostril***, the internal opening of the nasal cavity, which opens to the outside by the external nostrils as already described. Posteriorly in the roof of the cavity are two prominences formed by the bulging eyes. Still further behind in the back part of the buccal cavity or the ***pharynx***, as it is called, are the openings of the two ***eustachian canals***, one on either side. These are large

openings leading into the ***tympanic cavity,*** which is closed externally by the tympanic membrane. In the floor of the pharynx there is also

FIG. 56. Series of drawings of the frog at meal time. A frog flicks off any small moving object by the lightning-like snapping of its sticky tongue. It never chews but swallows its prey whole and alive. In never takes notice of any motionless food, however hungry it may be and however apetizing the food may be.

a raised area with a longitudinal slit, the ***glottis,*** through which the air passes into the lungs.

Oesophagus.—The pharynx narrows to form the ***gullet*** or ***oesophagus.*** The oesphagus is a straight muscular tube, smooth externally and running back below the backbone in the median longitudinal axis of the body. Internally its wall is thrown into numerous longitudinal folds.

Stomach.—Posteriorly the oesophagus enlarges to form the ***stomach.*** The transition between oesophagus and stomach is marked by an abrupt bend of the alimentary canal. The stomach is a slightly bent, smooth, pear-shaped, muscular bag, with the broader end near the oesophagus. Because in man this end of the stomach is close to the heart, it is called the ***cardiac end*** of the stomach. The posterior end of the stomach is guarded by a di sinct constriction called ***pylorus*** (=gate keeper), which marks the beginning of the intestine.

Intestine—The intestine commences behind the pyloric constriction. The first part of the small intestine is called ***duodenum*** (so called because in man this part of the small intestine is about twelve finger breadth long ; *duodeni*=twelve). It is a short tube sharply bent forwards from the stomach, to which it is parallel. It is attached to the stomach by a membrane called ***gastroduodenal omentum.*** The entry into the doudenum from the stomach is guarded by the ***pyloric valve.*** The small intestine again bends back posteriorly and is now looped several times. This part of the small intestine is called ***ileum.*** When the whole of the small intestine is straightened out, it is nearly five inches long. Finally, the ileum enlarges suddenly into a much wider, flask-shaped tube, about an inch long, the ***large intestine***, in the median line of the body. The large intestine passes into the ***cloaca***, which opens to the outside by the cloacal aperture. Into the cloaca opens ventrally the duct of a thin-walled, bilobed sac, the ***urinary bladder.*** The ducts from the reproductive organs and the kidneys also open into the cloaca.

Accessory digestive glands

The name gland is given to a cell or a group of cells, which synthesize a special ***secretion*** having definite chemical properties. The accessory digestive glands which are closely associated with the alimentary canal of the frog are two, viz. the ***liver*** and the ***pancreas***. There are no salivary glands in the mouth of the frog as in man, but there are mucous glands, which secrete the mucus to lubricate the food while swallowing.

The ***liver*** is one of the most important of the vital organs in the body of the frog. It is also the largest gland in the body. It is a large dark

reddish-brown mass, occupying a large part of the anterior abdominal region. It consists of three lobes : a right, a median and a left lobe. The left lobe is the largest and itself consists of two secondary lobes. This lobe hides the greater part of the stomach. The median lobe extends backwards as far as the pylorus and hides the duodenum. The right lobe extends much farther dorsally than the left lobe.

Dorsally, in a deep fissure between the right and the left lobes of the liver, there is a globose or oval, greenish-yellow vesicle, the ***gall bladder***. It has thin walls and is filled with the green ***bile***. The bile flows into the gall bladder from the liver by means of three ducts. These ducts arise from the lobes of liver, unite together into a single ***cystic duct***, opening anteriorly into the gall bladder. The bile passes from the liver and from the gall bladder into the intestine by a single ***bile duct***. Bile is a secretion of the liver and it is temporarily stored up in the gall bladder.

The ***pancreas*** is a flattened, elongated, yellowish-white organ. It lies in a fold of the gastroduodenal omentum between the stomach and the duodenum. The pancreas produces the ***pancreatic juice***. The common bile duct in its passage to the duodenum enters the pancreas. The duct of the pancreas joins the bile duct about the middle of its course and the common ***hepato-pancreatic duct*** opens into the duodenum dorsally a little beyond the pylorus.

FUNCTIONS OF THE PARTS OF THE ALIMENTARY CANAL AND OF THE ACCESSORY DIGESTIVE GLANDS

Events during digestion

The frog is a strictly carnivorous animal and its food consists of mostly small animals; like flies, worms, slugs and other smaller frogs, which are captured by a twinkling flick of the sticky tongue. The constituents of the food are thus exclusively the various complex proteins, fats and minerals occurring in the body of its prey. There are therefore *no* carbohydrates in the food of the frog, as is usually the case with the food of cow or man.

The frog never chews its food. Like most carnivorous animals it swallows its food whole and usually alive. The teeth in the buccal cavity are not therefore used in biting or masticating the prey but they prevent the slipping or escape of the animal. Copious flow of the mucus secreted by mucous glands helps in lubricating the food and thus facilitates its easy passage down the throat. No digestion thus takes place in the mouth of the frog, not only because the food does not stay there long enough but

also because there are no digestive glands like the salivary glands of man in the frog.

The wall of the oesophagus contains glands which secrete an alkaline fluid. This becomes active in the presence of hydrochloric acid in the stomach. The passage of food through the oesophagus is effected by ***peristalic contractions*** of the oesophageal wall. The oesophagus is a tube which is normally constricted but when the food enters it, the wall of the oesophagus in front of the food expands and as the food moves, it constricts behind. Successive contractions of the oesophagus thus push the food onwards to the stomach.

The food remains in the stomach for a considerable time. When it has entered the stomach, the cardiac end is closed to prevent the return of food into the gullet. The gastric glands now become active and pour out the gastric juice on the food. It is thoroughly mixed with the food by the churning movements of the wall of the stomach. Waves of contractions pass from the cardiac end to the pyloric end, churning, softening and mixing the food with the gastric juice. In course of time the body of the prey devoured by the frog actually begins to dissolve away due to the action of the gastric juice.

Gastric juice contains hydrochloric acid and an ***enzyme*** called ***pepsin***. An enzyme is a catalytic agent produced in a living organism. The exact chemical composition of enzymes is not clearly understood, but they are believed to be colloids very much resembling proteids in their composition. They have however the remarkable property that even minute quantities can transform very large quantities of the substance on which they act, without themselves entering into the reaction and being used up in the process or combined with the end products. Although several enzymes have been isolated by chemists, none has so far been artificially synthesized. Many of them cause hydrolysis by chemically adding a molecule of water to a molecule of the substance acted upon. They are mostly active between 30 – 45° C and are destroyed at 50 – 75° C. They are specific in their action, i. e., a given enzyme will act on a particular kind of substance. For example, ***protelytic*** enzymes hydrolyse proteids, ***lipolytic*** enzymes or ***lipases*** hydrolyse fats and ***amylases*** hydrolyse carbohydrates

Pepsin is a protelytic enzyme and therefore acts on the proteid part of the food of frog. It is effective only in the presence of hydrochloric acid. The complex insoluble proteids are hydrolysed step by step and ultimately converted into ***peptones*** and ***proteoses***. The food is now

partly digested and becomes a soupy mass called ***chyme.*** When this change has taken place, the pyloric valve opens bit by bit to permit the chyme to enter the duodenum.

In the duodenum the chyme meets the bile and the pancreatic juice from the hepato-pancreatic duct. The alkaline bile neutralizes the acidity of the chyme and thus enables the pancreatic enzymes to become active. Bile also breaks up the fats into minute droplets and thus emulsifies them.

The pancreatic juice is also alkaline and contains two important enzymes ***trypsin*** and ***lipase*** (= steapsin), which are active only in an alkaline medium. Trypsin now acts on the peptones, proteoses and the undigested proteids and changes all of them into ***polypeptides.*** The polypeptides are further acted upon by another enzyme ***erepsin*** contained in the ***intestinal juice*** secreted by the duodenum. They are now resolved to ***amino acids,*** which are the end products of protein digestion. Within the body the amino acids can be recombined to give rise to proteids once more.

Steapsin, the lipase of the pancreatic juice, acts on the fats which have already been emulsified by the bile. It now converts them into ***fatty acids*** and ***glycerol.*** The fatty acids have only a very short existence, because they are at once neutralized by the alkali of bile to produce collodial soap solutions.

In this way all the insoluble and non-diffusible constituents in the food have been converted into soluble or diffusible form, that is, they have been digested.

Absorption and assimilation

The process of digestion briefly outlined above has so changed the food that it can pass through the intestinal membrane by diffusion into the blood system, in other words can be ***absorbed.*** Most of the absorption takes place in the small intestine, because it is only here that the food arrives completely digested. The mineral salts and water are directly absorbed and do not undergo any digestion, because they are already soluble and diffusible.

The end products of protein digestion, viz. the amino acids, are absorbed by the mucosa, lining the small intestine, and pass into the blood stream going up the ***hepatic portal*** circulation (*see under Circulatory System*). From there they reach the liver before going to the various parts of the body.

9.30

The collodial soaps, derived as the end products of fat digestion do not diffuse directly into the blood vessels but they reach the parts of the body by another route. They pass into the ***lymph vessels*** which later empty into the blood stream.

The undigested part of the food now accumulates in the large intestine and cloaca. The material in the cloaca is thus largely rejected material and bacteria, which set up decomposition of the undigested matter. The cloacal contents are ejected as ***faeces*** through the cloacal opening.

Functions of the liver.—Strictly speaking, the liver is not a digestive organ, because it does not secrete any digestive enzyme. The bile, which emulsifies fats and also neutralizes the acidity of the chyme, is really in the nature of a waste product or an ***excretion*** of the liver. It is made up of worn-out blood cells and other waste matter. It consists of water, salts (especially sodium bicarbonate), bile acids, lipoids like cholesterin and lecithin, neutral fats, soaps, urea, etc. Its green colour is the result of the presence of decomposition products of the proteins of the blood.

It however helps digestion of fats by previously emulsifying them. Bile stimulates the peristaltic contraction of intestine and thus helps the passage of food. It has also an ***antiseptic*** action on the intestinal contents.

Excess proteids cannot be stored up in the body like carbohydrates or fats. The unused proteins and the protein wastes from the metabolism in the various tissues and organs of the frog are therefore ***deaminised*** by the liver. The amino acids are there converted into ammonia and a fuel giving part. The ammonia is as rapidly changed into urea as it is formed. The non-nitrogenous, easily oxidisable residue (fuel) is now converted by the liver into a carbohydrate called ***glycogen.*** Glycogen is either directly converted into blood sugar ***glucose*** and released into the blood stream or stored up in the liver as glycogen for future use.

Liver has therefore very vital functions to perform. Though not a digestive gland, complete digestion of food is impossible without the liver functioning normally. It is also responsible for assimilation of proteids and *creation* and regulation of the essential carbohydrates. Elimination of wastes of metabolism and purification of blood are effected by liver. In fact metabolism in the frog's body is possible just because there is a liver. Metabolism is life. The liver can

truly be compared to one leg of the tripod of life of frog, the two other legs being the heart and nervous system. As a tripod will fall, if any one of its three legs disappears, the importance of the work of liver will be readily understood.

Fate of the absorbed food : Uses of food

The absorbed food is carried by the blood stream to all the cells that go to build the body of the frog. There the food is used to produce energy, to carry on the vital activities and to repair and rebuild new protoplasm.

Before however the absorbed food can reach the cells of the body, the blood stream carrying the absorbed food (amino acids, fatty acids, glycerol, soaps, minerals and water) from the intestine, passes first to the liver., In the liver the amino acids are converted into urea and glycogen as already described. Glycogen is later changed to glucose and then let loose in the blood once more. This glucose is oxidised by the body cells to liberate the required energy. The rest of the amino acids is recombined in the body cells in the presence of other enzymes once more to produce the proteids that make the protoplasm of the frog's body. Fats are built into the structure of the protoplasm, or are directly oxidised to release energy.

The fate of the absorbed food is to be summarized thus :—

1. The absorbed protein is not stored but is used up as it comes.
2. The protein of food replaces the loss of protein of the body.
3. Rest of the protein is burnt up and the cumbustion products are eliminated and partly converted into carbohydrates.
4. Carbohydrates are used as sources of energy and excess is either stored as such or converted into fat.
5. Fats are stored and are burnt to provide energy.

The food is therefore used for the following purposes in the body of the frog :—

1. For production of the various forms of vital energy.
2. For repairing and rebuilding the cells, tissues and organs of the body, in other words to replace the loss of material and to create new living matter—protoplasm. Food is thus changed into life. metabolism
3. It enables the body of the frog to grow.
4. It is also stored up in the eggs to serve as food for the embryo.
5. It is stored up in the *fat bodies* to be used during hibernation and aestivation.

5. CIRCULATORY SYSTEM

Definition of circulation—The absorbed food and oxygen are continually carried to every part of the body. The effete waste products of metabolism are also removed promptly from every part and transported to those organs, whose function is to separate and expel them from the body. This process of interchange and transport of material—nutrients, oxygen, wastes, etc., in the body of an animal is called circulation. The organs specially concerned with circulation comprise the ***circulatory system***. The circulatory system is thus essentially a transport system.

The circulatory system of the frog comprises 1. ***blood circulation*** and 2. ***lymphatic circulation***. The essential parts of the former are (*i*) the ***blood*** the liquid medium of transport, (*ii*) the ***heart*** a central pumping station and (*iii*) tubular closed ***blood vessels*** or the highways of transport. The lymphatic circulation includes the ***lymph***, the ***lymphatic vessels***, in which it flows, and the ***spleen***.

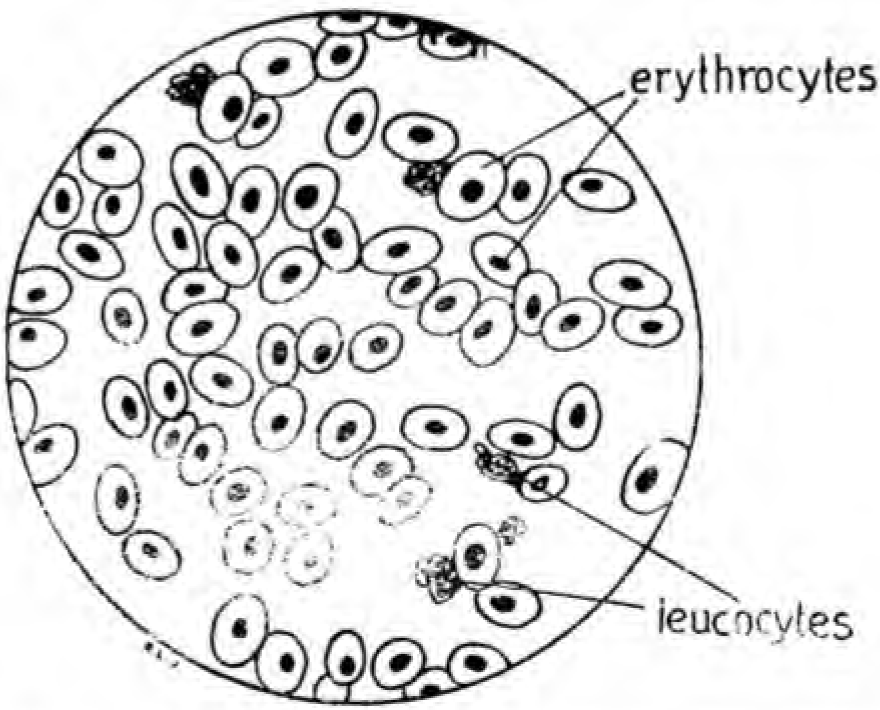


FIG. 57. A drop of frog's blood highly magnified. The erythrocytes of the frog are biconvex oval discs that have nuclei.

Blood.—The blood is the great medium of transport of material in the frog. It is a liquid tissue. The blood of the frog is an opaque, somewhat sticky, complex liquid, a little heavier than water. Its colour varies from bright scarlet to deep purple according as it is fresh

and contains oxygen or is exhausted of oxygen and is charged with waste products from the organs. It is slightly alkaline.

The blood is composed of a nearly colourless liquid, the ***plasma***, and of various solid bodies, ***the blood cells*** or ***corpuscles***.

The blood plasma is a clear, transparent, pale yellow liquid. Nearly ninety percent of it is water, the remaining solids, especially proteids. The blood proteins are fibrinogen, serum albumin, serum globulin and haemoglobin. Nutrient substances such as amino acids, soaps, fats, glucose, salts of potassium, calcium, magnesium, iron and especially sodium chloride (about 0.65%) are always present in varying quantities in blood. Waste materials like carbon dioxide and urea also occur in minute amounts. Special secretions like the ***hormones*** from the ***endocrine glands*** (*vide* Endocrine System) may also be found in the blood.

The corpuscles (Fig. 57) are of two kinds: 1. ***erythrocytes*** or ***haematids*** or ***red corpuscles*** and 2. ***leucocytes*** or ***amoebocytes*** or ***white*** or ***colourless*** corpuscles. The red corpuscles are far more numerous than the white corpuscles: there are about 400,000 red blood corpuscles per cubic millimetre of frog's blood. The red colour of the blood is due to the presence of the red corpuscles. Each red corpuscle is a biconvex oval disc, about 14 micra thick and 26 micra long. They have elastic walls and they can easily squeeze through passages narrower than themselves. They do not however have the power of spontaneous movement. In each red corpuscle there is a specialized central portion, the ***nucleus***, which has the power of being readily stained by certain dyes.

The red colour of the red corpuscles is due to the presence of an iron-containing proteid compound, ***haemoglobin***. The haemoglobin of the red corpuscle can be extracted with ether and crystallized in prisms. Haemoglobin has the remarkable property of readily combining with oxygen and thus giving rise to an unstable compound called ***oxyhaemoglobin***. This compound can just as readily decompose and give up its oxygen to the tissues of the body. The red corpuscles are therefore oxygen-carriers of the blood.

The colourless corpuscles are normally fewer than the red corpuscles and number about 7000 per cubic millimetre of frog's blood. They do not have a constant shape because they continually flow in various directions. They have the power of spontaneous movement and often pass out through the walls of the blood vessels and migrate to all

sorts of places. The protoplasm of the white corpuscle streams in the direction of movement, so that a bulging process called ***pseudopodium*** appears on that side. In the blood, the colourless corpuscles behave exactly like independent and complete organisms by themselves. In addition to the power of autonomous movements, they exhibit all the properties of life. Leucocytes respond to external stimuli. They also take food by surrounding any old and dead cells or any other foreign matter in the blood. They actually ingest fat globules when the blood passes through the intestine. They reproduce by dividing into two, each half growing into complete white corpuscles.

There are several kinds of colourless corpuscles. Certain kinds, the ***phagocytes***, are the policemen of the blood and do the work of invading and destroying foreign organisms They also remove old and dead cells of the body. Other kinds, the ***thrombocytes***, provide a substance called ***thrombin***, which acts on ***fibrinogen*** present in the plasma. The fibrinogen is a soluble blood protein. When thrombin acts on fibrinogen, the latter is converted into the insoluble ***fibrin*** threads, which form a close mesh entangling the corpuscles. Thus a blood ***clot*** is formed. The clotting of blood is a very important process of natural repair, for when a blood vessel is cut, a clot forms at the wound and stops bleeding.

The blood corpuscles have the following functions to perform :

1. The erythrocytes absorb the oxygen which is breathed in with the air and give it up to the tissues which are in need of it.
2. The leucocytes act as phagocytes or policemen of the body and destroy foreign organisms. This they do either by engulfing the organism and digesting them or by producing *bacteriolysins* which have the power of dissolving the bacteria.
3. They aid in the repair and regeneration of tissues.
4. They absorb fat from the intestine.
5. They help in maintaining the blood proteins.
6. They aid in the clotting of blood.

In addition to the corpuscles, blood also contains certain very important ***antibodies***. When any foreign disease-producing organism like a germ or a bacteria gets into the blood, a specific protective substance called ***antibody*** is usually produced in the blood. The antibodies destory the pathogenic foreigner and confer ***immunity*** to the animal from the attack of that particular agent.

The ventricular cavity is not smooth but is thrown into numerous spongy muscular ridges or ***trabeculæ***. The cavity of the ventricle does not extend right into the apex of the heart and it is also elongated in the transverse axis of the heart. The auriculo-ventricular opening is guarded by two flaps, the ***auriculo-ventricular valves***, springing from the ventricular wall. One of these flaps is dorsal and the other is ventral. The free margins of the valves are bound down to the ventricular wall below by a number of fine thread-like structures, the ***cordæ tendonæ***. The length of the cordæ tendonæ is such that they allow the valves to rise up and meet together so as to close the aperture but prevent them from pushing further into the cavity of the auricle. The valves therefore permit the passage of blood from the auricles to the ventricle but not back.

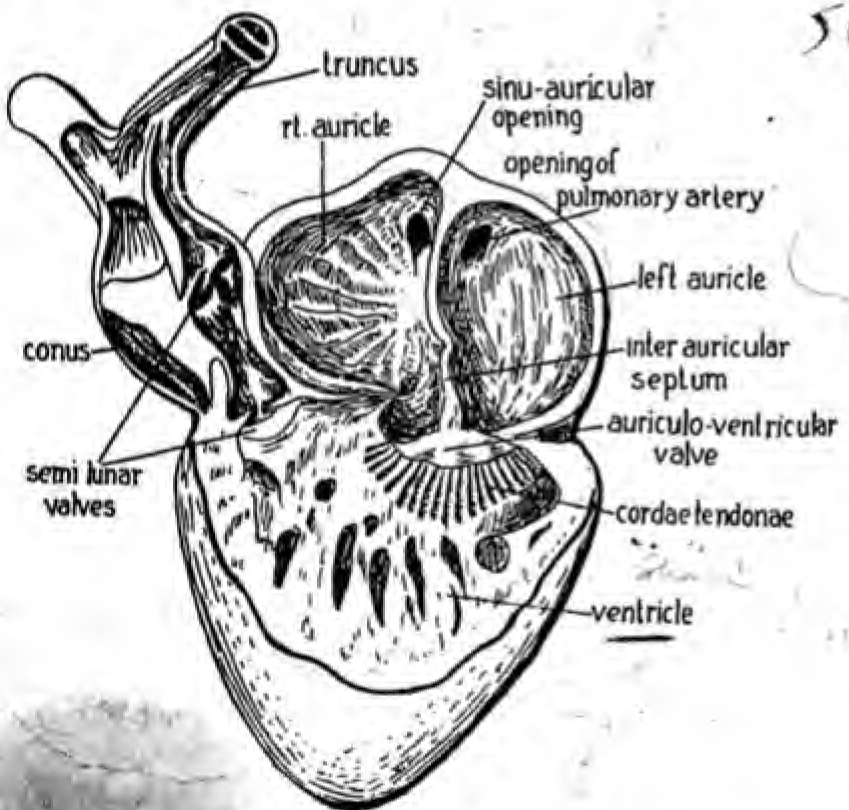


FIG. 60. The three-chambered heart of the frog cut open lengthwise to show the internal structure.

Blood vessels.—The blood vessels of the frog are of two kinds: ***arteries*** and ***veins***. The ***arteries*** are blood vessels with elastic muscular walls. They carry the blood from the heart to the various parts of the body. The arteries arise from the ventricle. They branch several times, become successively smaller, until they form a network of microscopic ***capillaries***,

which penetrate among the ultimate cells of the body. A capillary vessel is about one-hundredth of a millimetre in diameter and has lost the elastic coat of the arteries. The capillaries reunite together to form larger and larger vessels, the ***veins***, (Fig. 61) in which the blood, now impoverished of its food and depleted of its oxygen but charged with carbon dioxide and other waste products, flows towards the heart. Veins are thus blood vessels which convey the blood from parts of the body to the heart. To prevent the backward flow of blood, some of the veins have valves that open in the direction of the flow of blood to the heart. The blood is everywhere contained in vessels and not allowed to flow out between the cells. There is thus a ***closed*** circuit of blood vessels and the frog is thus said to have a ***closed circulation***, in contradistinction to an ***open circulation*** found in some other animals.

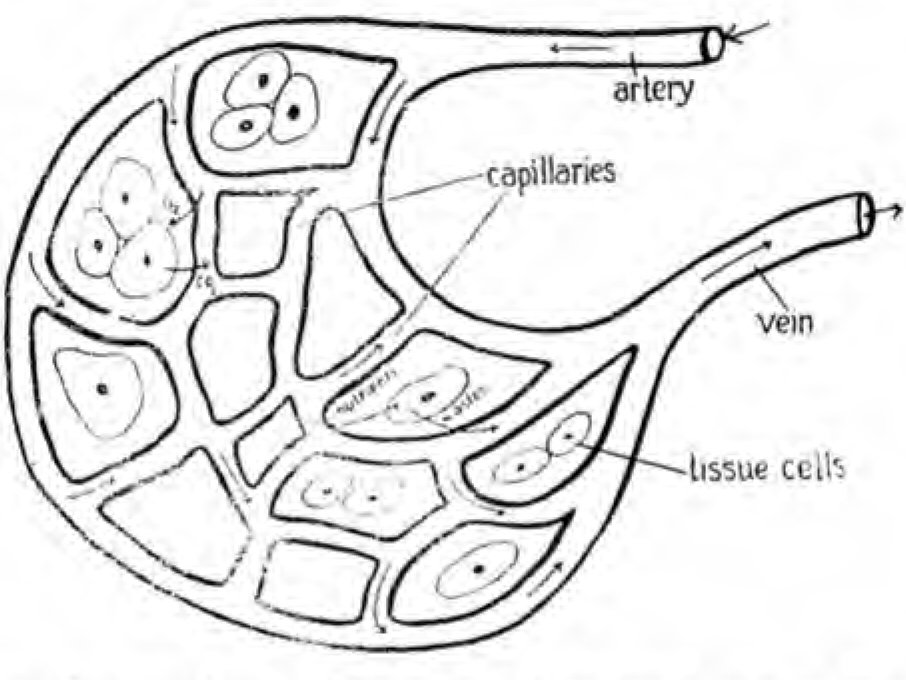


FIG. 61. Diagram showing the artery ramifying into a net-work of capillaries that unite again to from a vein. Exchange of material takes place between the tissue cells and capillaries.

Arterial system.—The arterial system of the frog begins in the ventricle of the heart as the ***conus arteriosus***. The conus arises from the right hand side ventrally from the base of the ventricle. It is a stout blood vessel which runs forward and to the left across the auricle to their anterior median border. Here it divides into a right and left ***truncus arteriosus***. Externally the conus appears as a single vessel but internally may be recognized a proximal ***phylangium*** and a distal ***synangium***. The opening of the ventricle into the conus is large and is guarded by ***semi-***

lunar valves, so called because of their half-moon shapes. The free edges of these valves are bound by cordæ tendonæ to the wall of the conus so that the blood can flow from the ventricle into the conus but not backwards.

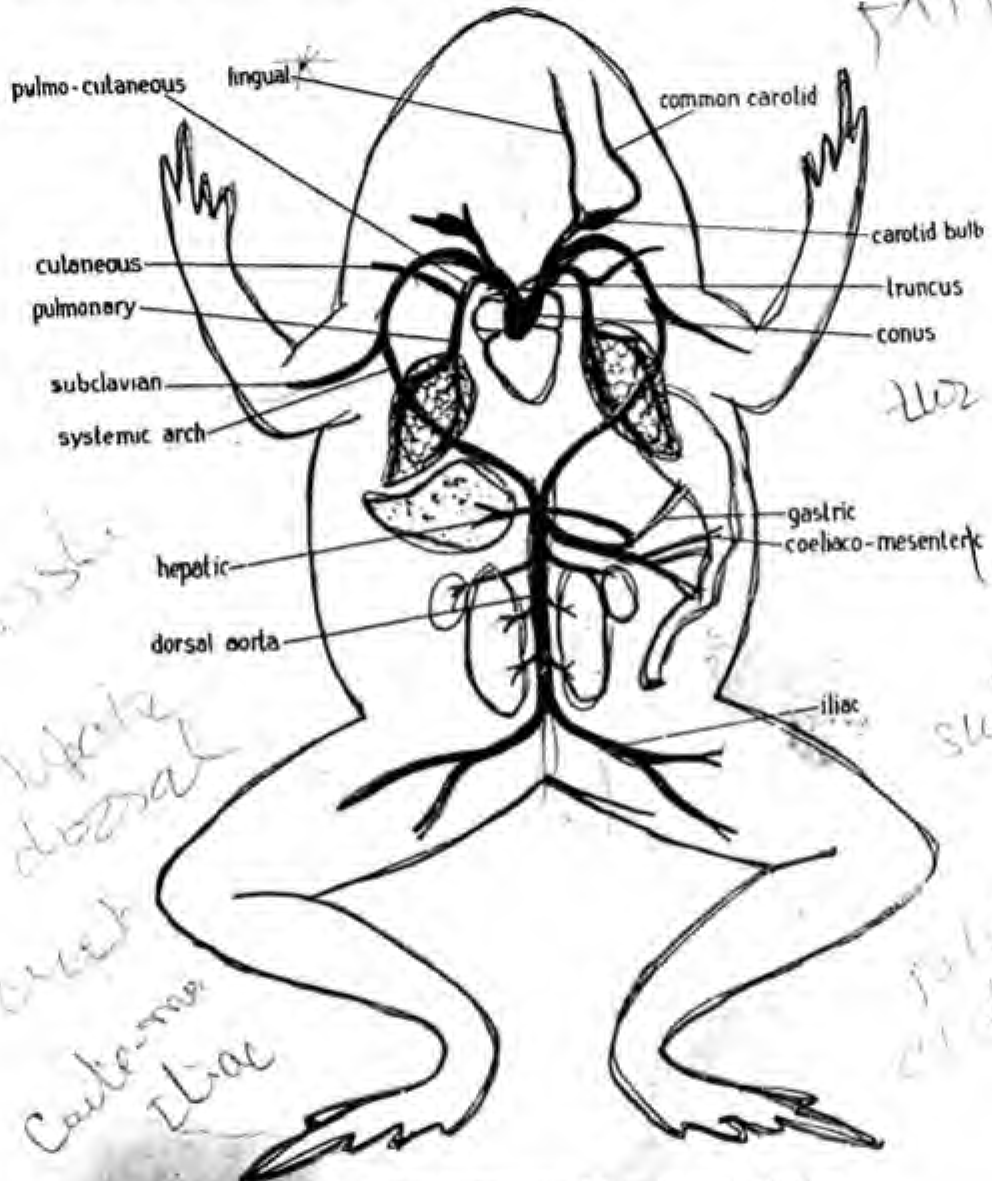


FIG. 62. Diagram of the arterial system of frog in ventral view.

The cavity of the conus (Fig. 63) is incompletely divided by a membranous ***spiral*** or ***longitudinal valve.*** The spiral valve commences ventrally close to the ventricular opening, runs spirally forwards to end dorsally on the right side in one of the semilunar valves between the phylangium and synangium. The ventral margin of the spiral valve hangs freely in the cavity of the phylangium. It thus incompletely divides the phylangium into a ***cavum aorticum*** or aortic chamber beginning on the ventral side and

* it is called external Car

curving round to the right and a ***cavum pulmocutaneum*** or pulmocutaneous chamber beginning dorsally and curving round to the left.

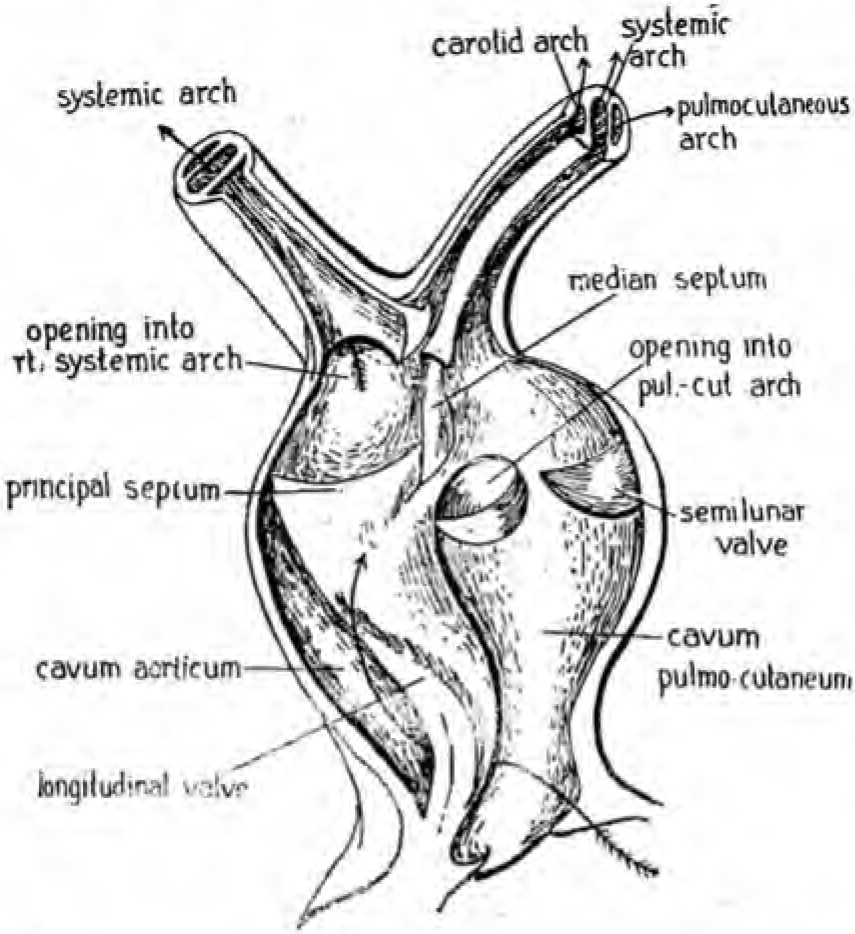


FIG. 63 Conus of the frog's heart cut open lengthwise to show the arrangement of the valves and indicate the direction of the flow of blood, that divides into three streams.

Beyond the end of the spiral valve is the distal part of the conus, viz. the synangium. This is a short but wide part of the conus and is separated from the phylangium by three semilunar valves. It is completely divided into a dorsal and a ventral chamber by a horizontal ***principal septum***. The dorsal chamber communicates with the cavum pulmocutaneum. The ventral chamber is further subdivided by a vertical ***septum medium*** into a right and a left half. The right passage communicates with the cavum aorticum.

Truncus arteriosus.—The truncus arises from the conus and almost immediately bifurcates. The two trunks are themselves made up of three vessels: an inner ventral ***carotid*** trunk, a median ***systemic*** trunk and a dorsal outer ***pulmocutaneous*** trunk. The carotid and

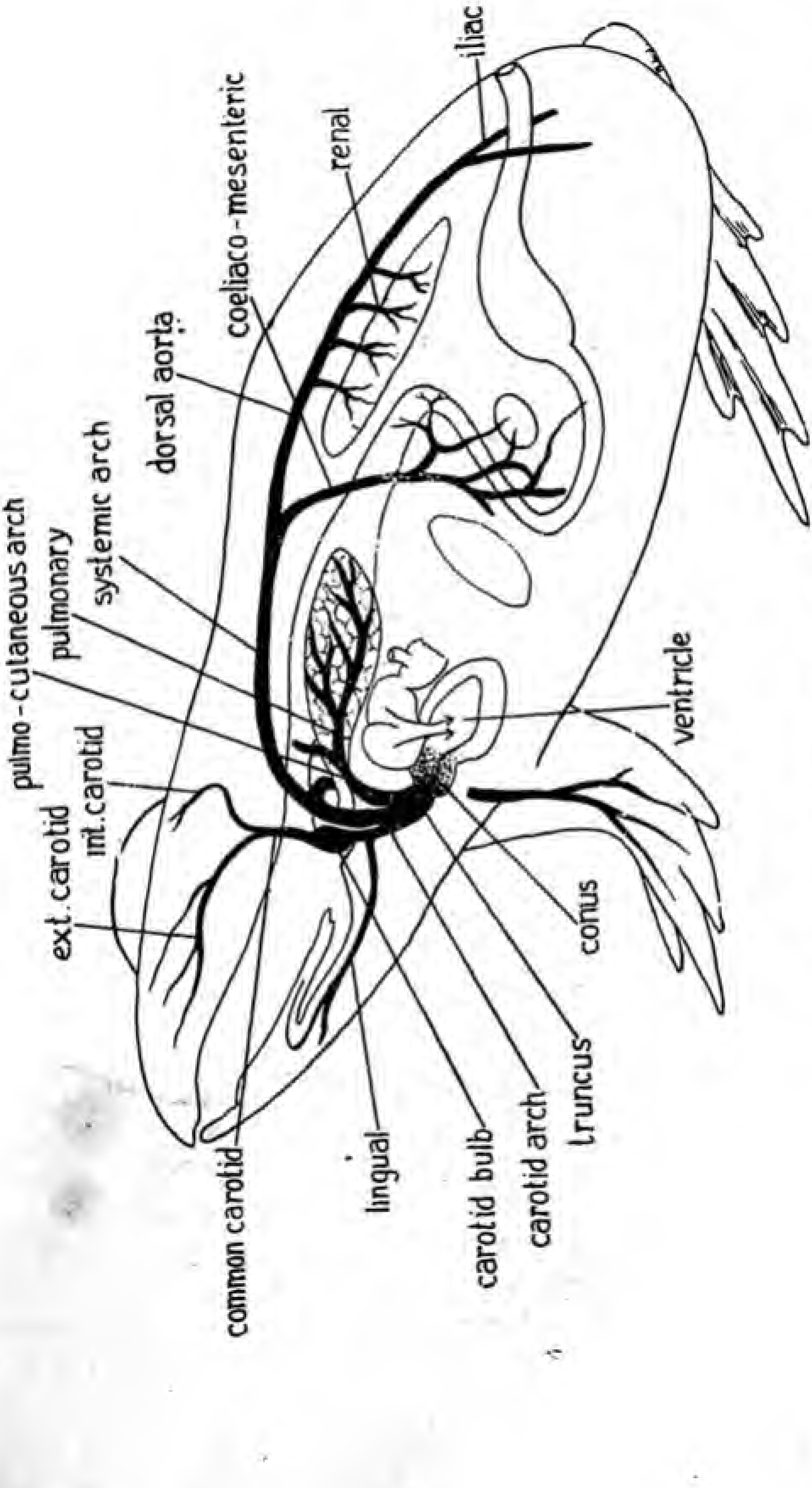


FIG. 64. Diagram of the arterial system of frog in lateral view.

the systemic trunks of the right side communicate with the right ventral passage formed by the septum medium in the synangium.

The left systemic aorta communicates with the left ventral passage of the synangium. The pulmocutaneous communicates with the dorsal chamber of the synangium. Each arterial trunk, soon after leaving the heart, divides into three arches, viz. the ***carotid***, the ***systemic*** and the ***pulmocutaneous arches.***

The carotid arch is the anterior-most of the three aortic arches. It curves round the side of the oesophagus to the dorsal surface. Shortly after its origin, it expands into a small globose ***carotid gland*** or ***carotid labyrinth***. Before expanding to form this gland, the carotid arch gives off a small ***lingual artery***,* which runs forwards and inwards over the throat and supplies blood to the tongue and thyroid gland. The main carotid artery continues from the outer border of the carotid gland. It runs round the oesophagus to the dorsal surface, where it takes a sharp turn anteriorly beneath the base of the skull. Here it divides into an ***external carotid***, whose branches supply blood to the pharynx and orbit and an ***internal carotid*** artery. The internal carotid enters the skull and supplies blood to the brain. Before turning anteriorly to run under the base of the skull the common carotid gives off a posterior ***ductus Botalli***.

The systemic arch.—The second trunk or the systemic arch coming from the truncus arteriosus also runs round the oesophagus to the dorsal surface, turns inwards and backwards to join its fellow of the opposite side. The right systemic arch then runs as a straight stout ***dorsal aorta*** posteriorly beneath the vertebral column. The left systemic arch opens into it by a small opening and then continues behind as the ***coeliaco-mesenteric*** artery. The coeliacomesenteric artery at once divides into a ***coeliac*** and a ***mesenteric*** artery. The coeliac artery gives off the ***gastric artery*** to the stomach and a ***hepatic artery*** to the liver. The mesenteric artery supplies branches to the spleen, kidneys, etc. Before uniting to form the dorsal aorta, the systemic arches give off: *i.* ***laryngeal artery*** to the larynx, *ii.* ***oesophageal*** artery to the oesophagus *iii.* ***occipitovertebral*** artery supplying the sides of the head and vertebral column and *iv.* ***subclavian*** artery supplying the shoulder and the fore limbs.

The dorsal aorta continues straight backwards and ultimately bifurcates to form the ***iliac arteries***. The iliac arteries continue posteriorly as the ***sciatic arteries*** into the hindlegs.

* This is called external carotid by some authors.

The pulmocutaneous arch is the posterior-most blood vessel from the truncus arteriosus. It runs forward and upward on the oesophagus. At the level of the carotid gland, it divides into the ***pulmonary artery*** which carries the blood to the lungs and the ***cutaneous artery*** distributed to the skin of the trunk.

SYNOPSIS OF THE ARTERIAL SYSTEM

The arterial system begins in the ventricle, which opens into the conus arteriosus. The conus continues as truncus arteriosus, which divides into two trunks. Each consists of carotid, systemic and pulmocutaneous arches.

***The carotid arch gives off*:**

1. Lingual artery to the tongue
2. Common carotid artery continues beyond the carotid gland and gives off an external carotid to the mouth and orbit and an internal carotid to the brain.

***The systemic arch gives off*:**

1. Laryngeal artery to the larynx
2. Oesophageal artery to the oesophagus
3. Occipitovertebral artery to the base of the skull and the backbone
4. Subclavian artery to the fore limb

The left systemic arch gives off at its point of union with the dorsal aorta:

Coeliacomesenteric artery, which soon divides into a coeliac and mesenteric branch.

***The dorsal aorta gives off*:**

1. Renal arteries to the kidneys
2. Ovarian or spermatic arteries to the reproductive organs
3. Iliac arteries, which continue as the sciatic arteries in the legs.

***The pulmocutaneous artery gives off*:**

1. Cutaneous artery to the skin
2. Pulmonary artery to the lungs.

Venous system.—The venous system of the frog comprises 1. the veins which convey the blood from the lungs to the heart, 2. the ***anterior veins*** which convey the blood from the head, throat and fore limbs and 3. ***posterior veins*** bringing the blood back from the viscera, legs, etc. The veins which bring the blood from the lungs reach the heart directly, but the anterior and posterior veins open into the sinus venosus.

VEINS WHICH OPEN INTO THE HEART

The pulmonary artery breaks up into capillaries in the lungs, where the carbon dioxide of the blood is exchanged for the oxygen of the air The capillaries unite to form the ***pulmonary vein***. The pulmonary vein

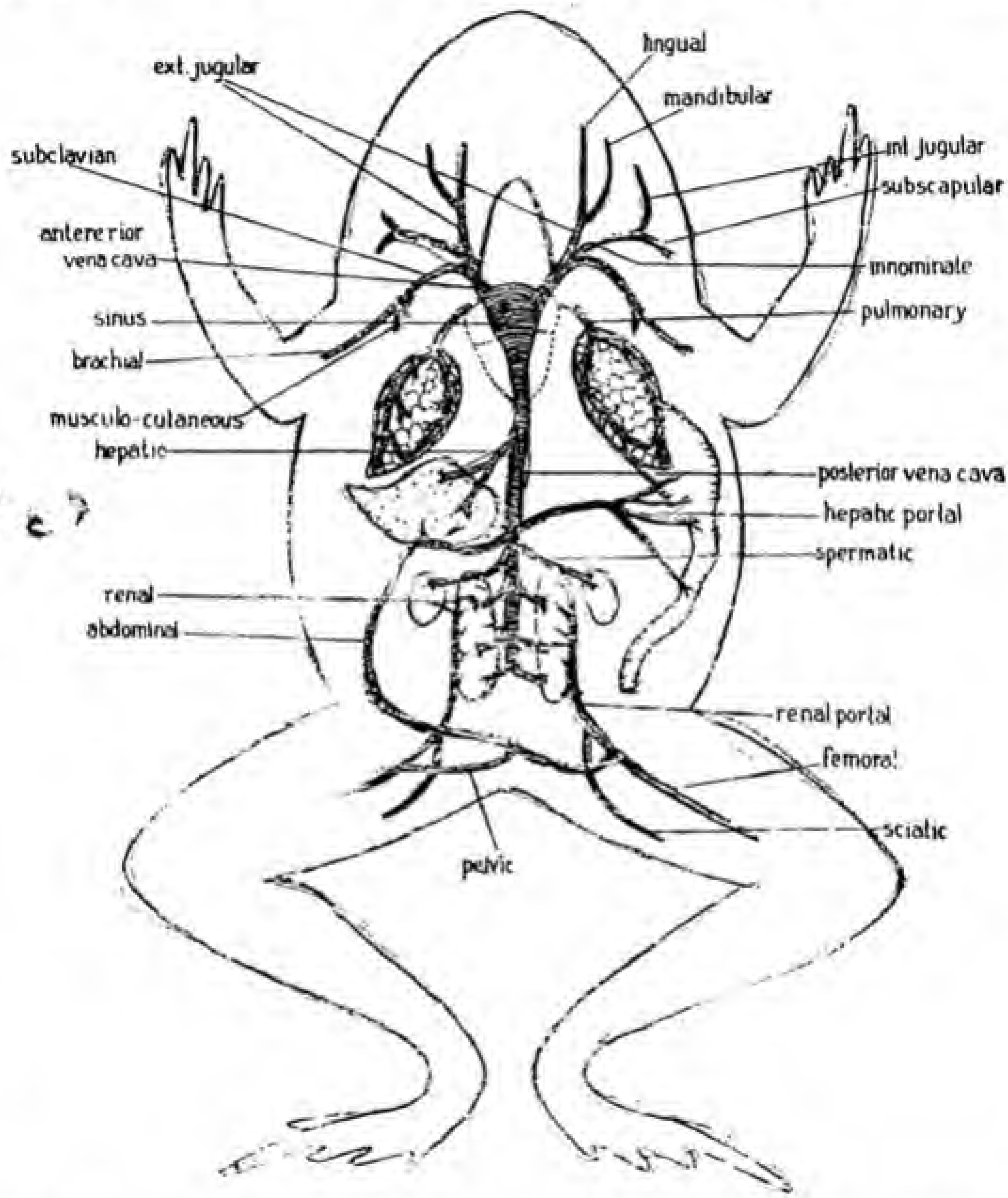


Fig 65. Diagram of the venous system of frog in ventral view. Anterior and posterior veins strippled and portals shown solid black.

therefore contains freshly oxygenated blood. The pulmonary veins of the two sides unite together into a common pulmonary vein, which opens antero-dorsally into the left auricle of the heart close to the inter-auricular septum.

VEINS OPENING INTO THE SINUS VENOSUS

Anterior veins.—The impure blood from the tongue returns by the ***lingual vein*** on each side. A ***mandibular vein*** coming from the lower jaw joins the lingual vein to form a short ***external jugular vein***. The ***internal jugular vein*** brings the blood back from the brain and inside the head. This is joined by the ***subscapular vein*** from the shoulder to form the ***innominate vein***. The blood from the fore limbs returns by the ***brachial vein***. A ***musculocutaneous vein*** bringing the blood back from the body wall muscle and from the skin joins with the brachial to form a ***subclavian vein***.

The external jugular, the innominate and the subclavian veins of each side join together to form a stout common ***anterior vena cava*** or ***precaval vein***. Each anterior vena cava opens into the sinus venosus at its antero-lateral angle.

Posterior veins.—The posterior venous system of the frog comprises : 1. a systemic, 2. a renal portal and 3. a hepatic portal system. The venous blood from the trunk, viscera, hind limbs and other organs posterior to the heart do not return directly to the heart but the veins once again break up into capillaries either in the kidneys or in the liver before rejoining to form the ***posterior vena cava***, or the ***post caval vein***, which opens into the sinus venosus posteriorly. When the veins thus enter an organ on their way to the heart we have a ***portal circulation***. There are two portal circulations in the frog : a ***renal portal*** and a ***hepatic portal*** circulation.

The venous blood from the hind limbs returns by 1. the ***femoral vein*** and 2. the ***sciatic vein***. The femoral vein is the larger of the two and runs forward, downward and outward to reach the ***pelvis*** or the hip. Here it bifurcates to form a ***pelvic vein*** and an ***iliac vein***.

The sciatic vein runs forward and joins the iliac vein. The common vessel thus formed is termed the ***renal portal vein***. The renal portal vein continues forward and gives off small branches which enter the kidneys and break up into capillaries within the kidneys. Here the kidney cells remove the waste products urea and carbon dioxide from the blood. The capillaries reunite to ***renal veins***. Four to six renal veins leave each kidney, join together to form a stout ***posterior vena cava***, which runs forward to open into the sinus venosus.

The pelvic veins of the two sides run inward to the median ventral line of the abdominal wall, where they unite together into an unpaired large

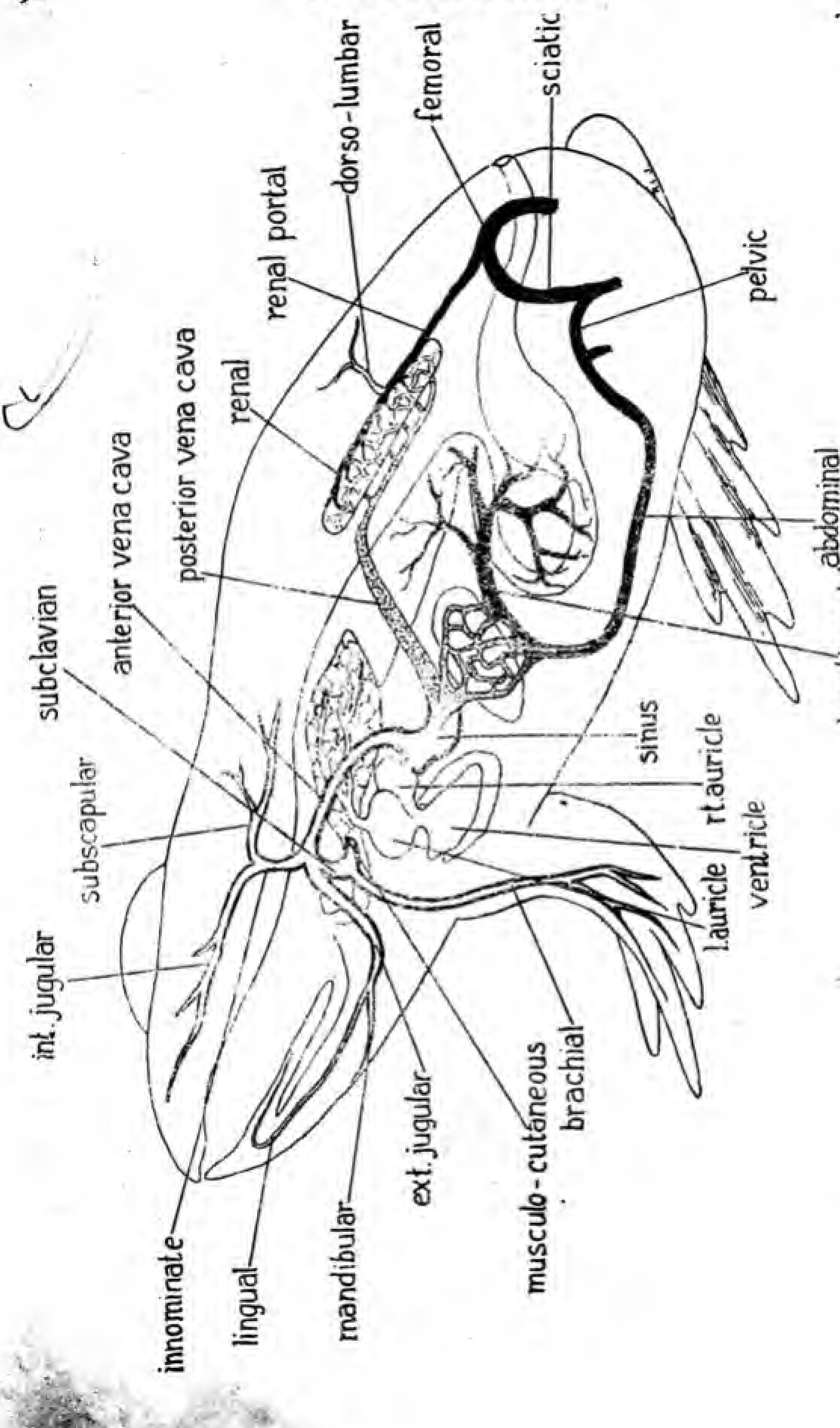


FIG. 66. Diagram of the venous system of frog in lateral view. Anterior veins shown without shading, postcaval vein dotted and portal circulation in solid black.

median ***anterior abdominal vein***. The anterior abdominal vein runs in the median line on the ventral wall of the body up to the sternum or breastbone. Here it runs inward and gives off two lateral branches and one median branch. The lateral branches enter the right and the left lobes of the liver and break up into capillaries. The median branch unites with the ***hepatic portal vein***.

The ***hepatic portal*** vein is formed by the union of the ***intestinal, gastric*** and ***splenic veins***, bringing the blood respectively from the intestine, stomach and spleen. The intestinal vein contains the blood with the absorbed food material. The hepatic portal enters the left lobe of the liver and breaks up into capillaries. Here the liver cells remove the excess of amino acids from the blood and liberate glucose into the blood. The capillaries reunite and the blood leaves the liver by the ***right*** and ***left hepatic veins***, which open into the posterior vena cava before the latter ends in the sinus venosus. Thus the blood from the parts of the body behind the heart can only return to the heart either through the kidneys or through the liver but not direct.

SYNOPSIS OF THE VENOUS SYSTEM

The venous system comprises:

1. Pulmonary vein, 2. anterior veins and 3. Posterior veins.

1. The Pulmonary vein begins in the lungs and opens into the left auricle.
2. The anterior vena cava opens into the sinus venosus and is formed by the union of :
   - (i) External jugular vein formed by the
     - (a.) lingual from the tongue and.
     - (b.) mandibular from the lower jaw,
   - (ii) Innominate vein formed by the
     - (a) internal jugular from the skull and
     - (b) subscapular from the shoulder
   - (iii) The subclavian formed by the
     - (a) brachial from the fore limb and
     - (b) musculocutaneous from the body wall and the skin.
3. The Posterior vena cava opens into the sinus venosus and is formed by :
   - (i) The renal portal system and
   - (ii) The hepatic portal system.
     - (i) The renal portal system
       - (a) The iliac vein and sciatic vein unite to form the renal portal vein

(b) The renal portal vein breaks up into capillaries in the kidneys
(c) The capillaries rejoin into the renal veins
(d) The renal veins join to form the posterior vena cava.

(ii) The hepatic portal system
(a) The pelvic veins unite into anterior abdominal vein
(b) The anterior abdominal vein breaks up into capillaries in the liver
(c) The gastric and intestinal veins unite into the hepatic portal vein, which also breaks up into capillaries in the liver
(d) The capillaries reunite to form the hepatic vein, which opens into the posterior vena cava.

Mechanism of circulation: Events during circulation

The blood is forced under pressure through the arteries by the pumping action—contraction of heart. A contraction followed by relaxation of the heart forms one complete ***heart beat***. All parts of the heart do not contract at the same time but the contractions pass in a wave-like manner from the sinus to the auricles, then to the ventricle and finally to the conus. The contracted state is called ***systole*** and the relaxed state is called ***diastole***. The heart continues to beat ceaselessly, taking short rests between successive contractions. The beat of the heart is therefore described as ***rhythmic***. There is a regular sequence of systole, diastole, pause for rest, systole, diastole, pause and so on. In the case of the frog and other similar cold-blooded animals, the heart continues to beat long after the death of the animal.

The beat of frog's heart commences in the sinus venosus, which has received the impoverished blood from the precaval and postcaval veins. The sinus venosus contracts and thus forces the venous blood through the sinu-auricular opening into the right auricle. At the same time the left auricle is filled by the freshly oxygenated blood returning from the lungs through the pulmonary vein. The sinus relaxes and the valves guarding the sinu-auricular opening close. The two auricles now contract simultaneously and thus force the blood into the ventricle through the auriculo-ventricular aperture. The impure venous blood from the right auricle and the pure oxygenated blood from the left auricle both fill the elongated cavity of the ventricle. The pure blood flows on the left side and the impure blood on the right side, with a mixture of the two kinds in the middle. The ventricle contracts, immediately after the auricles, allowing no time for

mixing up of the pure and the impure blood. The auriculo-ventricular valves close and thus prevent a return of the blood to the auricles. The venous blood on the right side being immediately in front of the opening of the conus, passes first into the conus, which now contracts. In the phylangium, the blood is directed by the longitudinal valve and passes from the dorsal side to the right and finally to the ventral side. The venous blood passes over the free border of the upper end of the longitudinal valve and enters

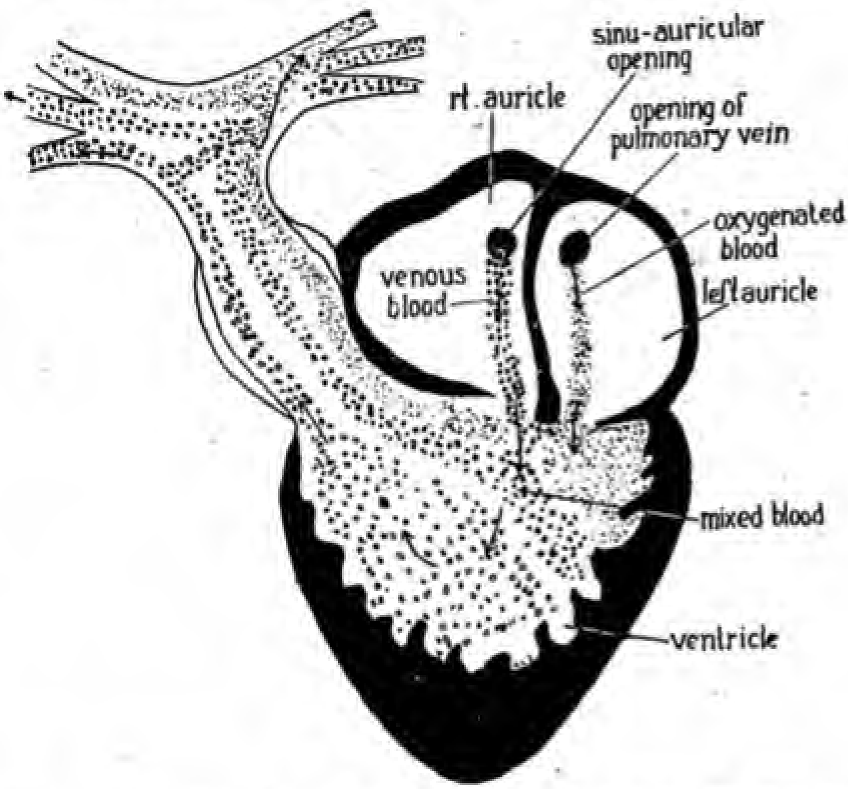


FIG. 67. Diagram of the flow of blood within the heart. The fine dots represent the freshly oxygenated blood entering the left auricle from the opening of the pulmonary vein. It is the first stream that flows out when the ventricle contracts and enters the carotid arch that supplies the head. The larger dots represent the mixture of oxygenated and venous streams that flows next and enters the systemic arch to supply the general viscera. The small circles represent the venous stream coming into the right auricle through the sinu-auricular aperture. It flows last of all and enters the pulmo-cutaneous arch, whence it reaches the lungs and the skin for oxygenation.

the cavum pulmocutaneum. In the synangium the blood enters the pulmo-cutaneous artery and goes to the lungs and skin for oxygenation. The next portion of the blood from the ventricle, a mixture of pure and impure kinds, enters the systemic arches and finally the purest blood from the left side of the ventricle passes into the carotid arches.

SYNOPSIS OF EVENTS DURING THF BEAT OF THE HFART

1. Venous blood fills the sinus venosus.
2. The sinus contracts.
3. The blood flows from the sinus into the right auricle ; freshly oxygenated blood from the lungs fills the left auricle.
4. The auricles contract.
5. Both kinds of blood flow into the ventricle.
6. The ventricle contracts.
7. The venous blood flows first, next a mixture of pure and impure and finally the pure blood flows into the conus.
8. The conus contracts, the venous blood being directed by the longitudinal valve into the pulmocutaneous artery, goes to the skin and lungs for oxygenation.
9. The mixed blood is next driven to the systemic arches and goes to supply the posterior parts of the body.
10. Oxygenated bleed (last part) is now driven into the carotid artery and goes to the head.
11. One complete beat of the heart is over.

Lymph.—The lymph is a clear, transparent liquid containing colourless corpuscles. It differs from blood in not having red corpuscles. It is derived from the blood filtering-out through the blood vessels, leaving the red corpuscles behind.

The lymph is present in ***lymph sinuses*** beneath the skin. Lymphatic vessels are found in the walls of the intestine to absorb the digested fats. They are called ***lacteals***, because they contain a milky ***chyle***, which they discharge into the venous system. Two pairs of lymph hearts keep the lymph circulating in the frog. One of these hearts lies beneath the shoulder bones and other in the posterior region of the body.

The spleen.—The spleen is a small globose reddish-brown gland near the anterior end of the large intestine. The spleen manufactures the colourless corpuscles of the lymph and blood. Old and unhealthy red corpuscles are destroyed in the spleen. Further mention of the spleen will be made under the Endocrine System.

6. RESPIRATION

Respiration is the transformation of food into energy by the slow oxidation or "physiological burning" of food in the body of an animal, with the help of the oxygen that is breathed in. The removal of carbon dioxide resulting from this oxidation is also a part of respiration. Respiration

is thus not merely breathing. It is really exchange of oxygen for carbon dioxide and the transformation of the food into energy. The exchange of oxygen of the air for the carbon dioxide of the blood is called ***external respiration*** and that between the blood and the body cells is ***tissue*** or ***internal*** (true) ***respiration.***

Types of respiration in the frog.—The frog is able to extract the small quantity of oxygen (0.7%) dissolved in water and to give up carbon dioxide to the water by its skin. It is also able to breathe the abundant oxygen (21%) of the air into the lungs. There are therefore two types of respirations in the frog : ***cutaneous*** or skin respiration and ***pulmonary*** or lung respiration. The moist skin is richly supplied by capillaries from the cutaneous artery. In the capillaries the blood is separated from water by a very thin membrane. The red corpuscles of the blood readily absorb the oxygen from the water and the plasma gives up its carbon dioxide to the water. In pulmonary respiration, the gaseous exchange between the blood and the air takes place within the lungs.

Respiratory organs.—The frog has a primitive respiratory system. The organs of pulmonary respiration in the frog are: *i.* the external nares, *ii.* the internal nares, *iii.* the buccal cavity, *iv.* glottis, *v.* laryngo-tracheal chamber, *vi.* the bronchi and *vii.* the lungs.

The external and internal nostrils and the glottis have already been described. The buccal cavity is also used in breathing. The mucous membrane lining the buccal cavity dissolves a certain amount of oxygen, which is then absorbed by the blood in the capillaries.

Larynx.—The glottis or the slit-like aperture on the floor of the buccal cavity opens into a stout, short tube, the ***larynx***, which is strengthened by fine semi-elastic cartilages, of which one is single and the rest are paired. These are the oval ring-like ***cricoid cartilage***, with the paired ***arytenoid*** cartilages in front. The latter are stronger and larger in the male than in the female frog. There are two ***pre-arytenoid cartilages*** in front of the arytenoids.

The cavity of the larynx is constricted anteriorly and posteriorly. The larynx bifurcates posteriorly to form the ***bronchi***, which enter the lungs.

Lungs.—The lungs of the frog are simple, elastic, spongy sacs, situated one on either side of the heart. They are richly supplied with blood. There are numerous small chambers or ***alveoli***. The alveoli are lined by capillaries of the pulmonary artery and have moist surfaces. The oxygen of the air, which is breathed in, dissolves in the surface moisture and

diffuses into the blood. The haemoglobin of the red corpuscles absorbs the oxygen and later releases it to the tissues which require it. The carbon dioxide liberated by the tissues is mostly dissolved in the plasma and passes out into the air of the alveoli to be breathed out of the lungs.

Respiratory movements : Mechanism of respiration

The mechanism of respiration in the frog consists in alternate breathing-in of air into the lungs or ***inspiration*** and breathing-out of air or ***expiration***. The frog closes the mouth and depresses the floor of the buccal cavity, thus drawing in a quantity of air through the external nostrils. The air passes through the nasal cavity and enters the buccal cavity by the internal nostrils. When the buccal cavity is filled by air, the external nostrils are closed by a flap of skin thus preventing the escape of the air. The floor of the buccal cavity is now forcibly raised, thus compressing the enclosed air. This air is therefore forced through the glottis into the larynx and thence into the lungs. Inspiration is thus completed. In the lungs it

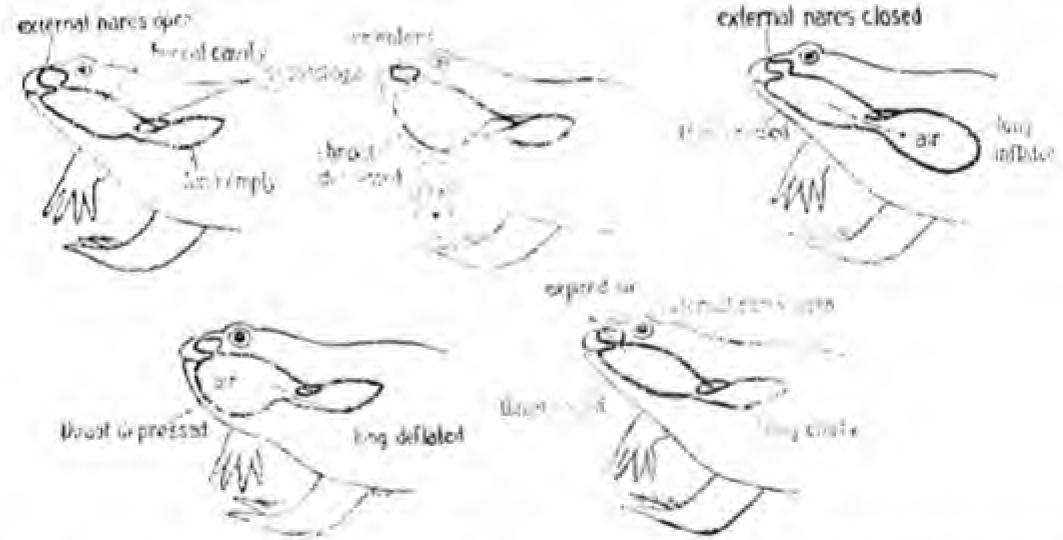


FIG. 68. Series of drawings to show the respiratory movements and illustrate the mechanism of respiration in the frog. The respiratory apparatus of the frog may be compared to a force pump, which forces the air in and out of the lungs. The buccal cavity plays the role of the force pump.

fills the alveoli, where the gaseous exchange takes place. The floor of the buccal cavity is again depressed and the air from the lungs, having given up its oxygen and having absorbed carbon dioxide, rushes back into the buccal cavity. The external nostrils are opened and the air is finally forced out by the raising of the floor of the buccal cavity once more. Expiration is thus completed. In breathing on land, a frog must therefore keep its mouth closed, since the volume of the buccal cavity is changed by the movements of the wall of the throat.

Voice.—The respiratory organs are also responsible for the production of voice—the croaking of the frog. Two ***vocal cords*** or vertical flat bands of connective tissue are attached to the arytenoid cartilages. The vocal cords leave a slit-like opening or ***rima glottidis*** between them. Croaking is produced by the vibration of the edges of the vocal cords, when air is forced vigorously through them from the lungs. Male frogs croak much more loudly than female frogs and the vocal sacs of the male become inflated with air and amplify the sound. Only air-breathing animals have vocal cords and thus have a 'voice' ; fishes do not have either.

7. URINOGENITAL SYSTEM

The urinary and genital systems of organs of the frog consist of the ***excretory system*** and the ***reproductive system.*** These two systems are usually considered together, because they have largely a common origin and also because the products of the reproductive organs often pass through the ducts of the excretory system. Functionally however the two sets of organs are completely unrelated.

Excretory system

The excretory system of the frog has the special function of separating the waste products of metabolism from the blood and expelling them from the body. The waste products of metabolism, *viz.* urea, carbon dioxide and water, are gathered by the blood stream in the course of circulation. If these products are not promptly and continually eliminated from the blood, but allowed to accumulate, fatal results will ensue. The removal of these waste products is called ***excretion*** and often the waste products are themselves called ***excretory products*** or simply ***excretions.*** Excretions are chiefly urea, water and carbon dioxide, in other words the useless products of life-activity; faeces is thus not an excretory product, because it never entered into the metabolic activity of oxidation of food in the tissues.

The excretory organs of the frog are the skin, liver, lungs, kidneys, ureters, urinary bladder and the cloaca.

The skin of the frog is an important excretory organ. It excretes a considerable amount of superfluous water and also large quantities of carbon dioxide.

The liver performs, in addition to the functions already mentioned, important excretory functions also. It is in this organ that ammonia, a product of amino acid decomposition, is built up into *urea* and put into the blood stream to be expelled by the kidneys. The liver also excretes the important waste product ***bilirubin***, resulting from the disintegration of the

haemoglobin when erythrocytes of the blood die. Bilirubin is the chief colouring matter of bile. ***Cholesterol*** is another waste product, derived partly from the death of red corpuscles and excreted by the liver. Certain toxic agents, drugs and metals like copper, are eliminated from the body by the liver through bile.

The lungs, which are strictly speaking respiratory organs, should also be considered as one of the excretory system. The excretion of carbon dioxide is largely the work of lungs. The exhaled air contains considerable quantities of this gas.

Kidneys.—The kidneys are the chief excretory organs of the frog. They are a pair of elongate oval, flat, dark-red, lobulated organs, attached to the dorsal body wall, one on either side of the median line. They are situated in a lymph space. The inner border of each kidney is straight and the outer border convex. Each kidney is somewhat thinner posteriorly than anteriorly. It is about 15 mm long and 5 mm broad.

There are two distinct notches on the inner border of each kidney, the posterior-most being the deepest. Each notch extends as a groove and contains a branch of the renal portal vein. A kidney is enclosed in a thin capsule. It is made up of malpighian corpuscles, uriniferous tubules and collecting tubes.

Ureters.—The ureter begins from the dorsal surface of the kidney and is continuous with the collecting tubules inside the kidney. It lies wholly on the dorsal surface in the anterior part of the kidney but posteriorly, in a groove on the outer border of the kidney, along with the renal portal vein. Each ureter runs backward and converges posteriorly to its fellow of the opposite side. The two ureters thus open close together but separately into the cloaca from the dorsal side.

Urinary bladder.—The urinary bladder is a large membranous sac attached ventrally to the cloaca, into which it opens. It is distinctly bilobed and has a narrow neck by which it is attached to the cloaca.

Mechanism of separation of urine.—The blood is brought to the kidneys by the renal portal veins and by the renal arteries. These break up into a network of capillaries called ***glomerulus.*** Each glomerulus projects into a double-walled ***Bowman's capsule.*** The glomerulus and the Bowman's capsule together constitute a ***Malpighian corpuscle.*** The capillaries of the renal portal vein supply the tubules. As the blood passes through the glomerulus, the capsule cells filter off the urea, carbon dioxide and excess of water and thus form the ***urine.*** The purified blood passes onwards to the renal veins and thence to the heart as described above.

The urine passes down the uriniferous tubules and reaches the ureters. From there it flows into the cloaca. As the excretion of urine is a continual process but as the cloacal aperture is closed except at defaecation, the urine which drips into the cloaca runs by gravity into the urinary bladder, where it is stored until a sufficient quantity has collected for forcible ejection through the cloacal aperture.

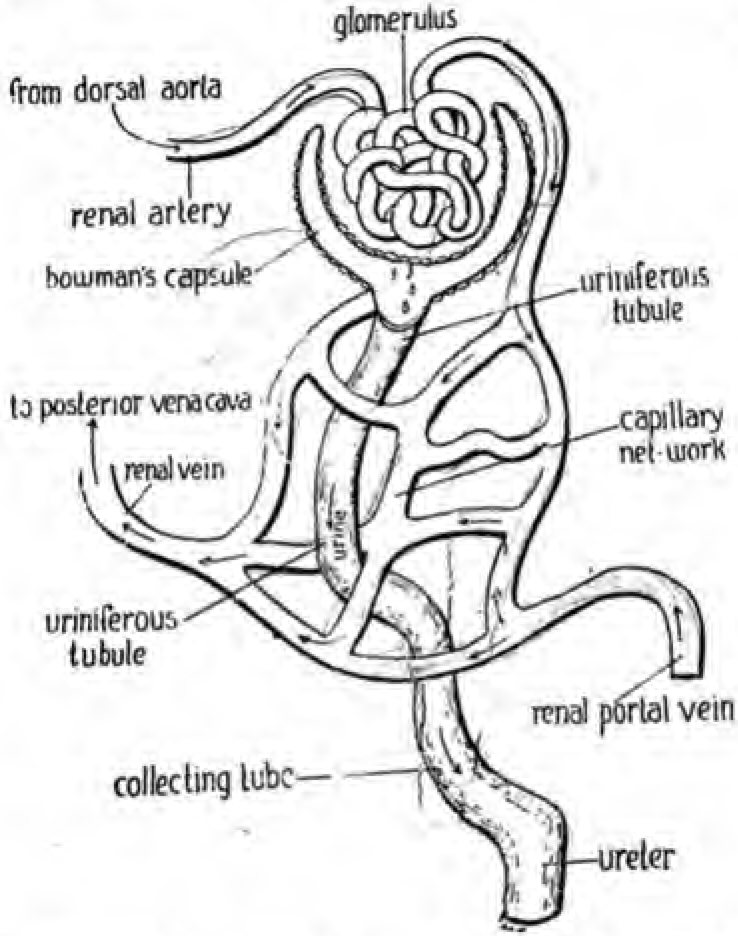


FIG. 69. Diagram showing the relation of the blood capillaries to the urine secreting tubules in the kidney of frog.

Urine contains water, urea, traces of carbon dioxide and the pigments bilirubin and cholesterol.

Reproductive system

The reproductive system of the frog consists of the ***gonads*** or the reproductive organs, in which the ***germ cells*** are formed, and the ***reproductive ducts***, through which the germ cells leave the body. There are two sexes: individuals of the frogs are either ***males*** or ***females***. The gonads and their ducts differ in the male and female frogs.

The male reproductive organs.—In the male frog the gonads are called the ***testes***. Each testis is a coiled mass of ***seminiferous tubules***, along the walls of which the male germ cells—***sperms*** or the ***spermatozoa*** are produced. It is a pale yellow, oval organ, attached by a membrane called ***mesochorium*** to the dorsal body wall. It lies ventrally on the anterior end of the kidney. Each testis is attached to the kidneys by a number of fine tubules called ***vasa efferentia***. The vasa efferentia open into the collecting tubes of the kidneys. These collecting tubes in their

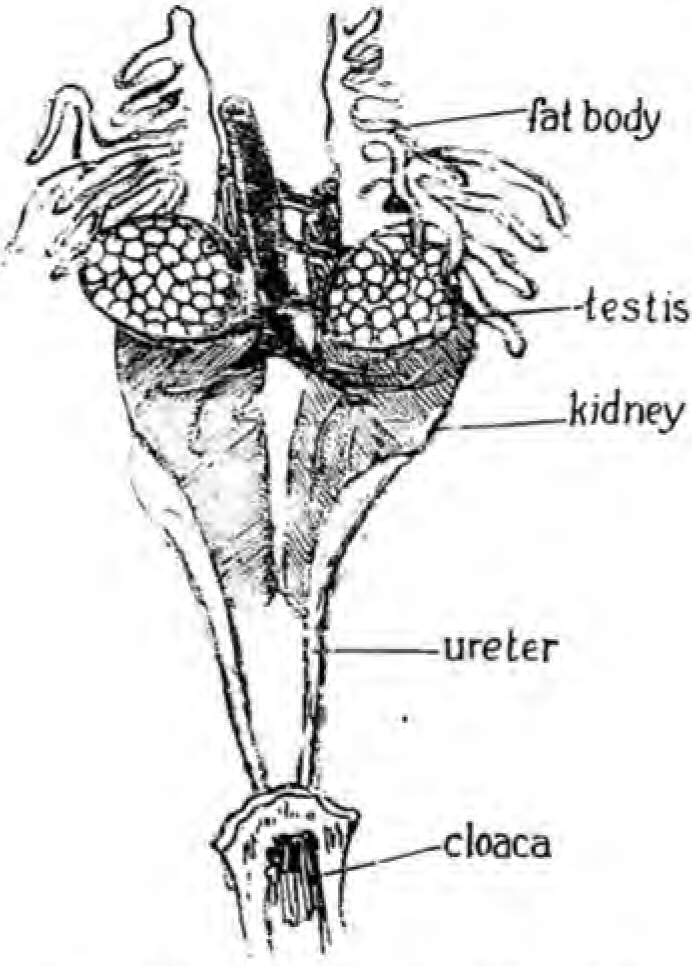


FIG. 70. Reproductive organs of the male frog.

turn open into the ureter. The ureter has a bag-like expansion, the ***vesicula seminalis*** or seminal vesicle. The seminal fluid, containing the spermatozoa produced in the testes, passes through the vasa efferentia into the collecting tubes of the kidneys and thence by the ureter to the seminal vesicle, where it is stored up till required. In the breeding season, the male frog climbs over the female and sheds his sperms from the cloaca over the eggs discharged at the same time by the female. Thus in the male

frog the ureters serve not only for the passage of the excretory liquid, but also of the reproductive fluid.

In front of the testes there are paired branched growths, the ***fat bodies***. The fat bodies provide a reserve of nutriment for the formation of the semen and during the hibernation or aestivation of the frog, when no feeding is possible.

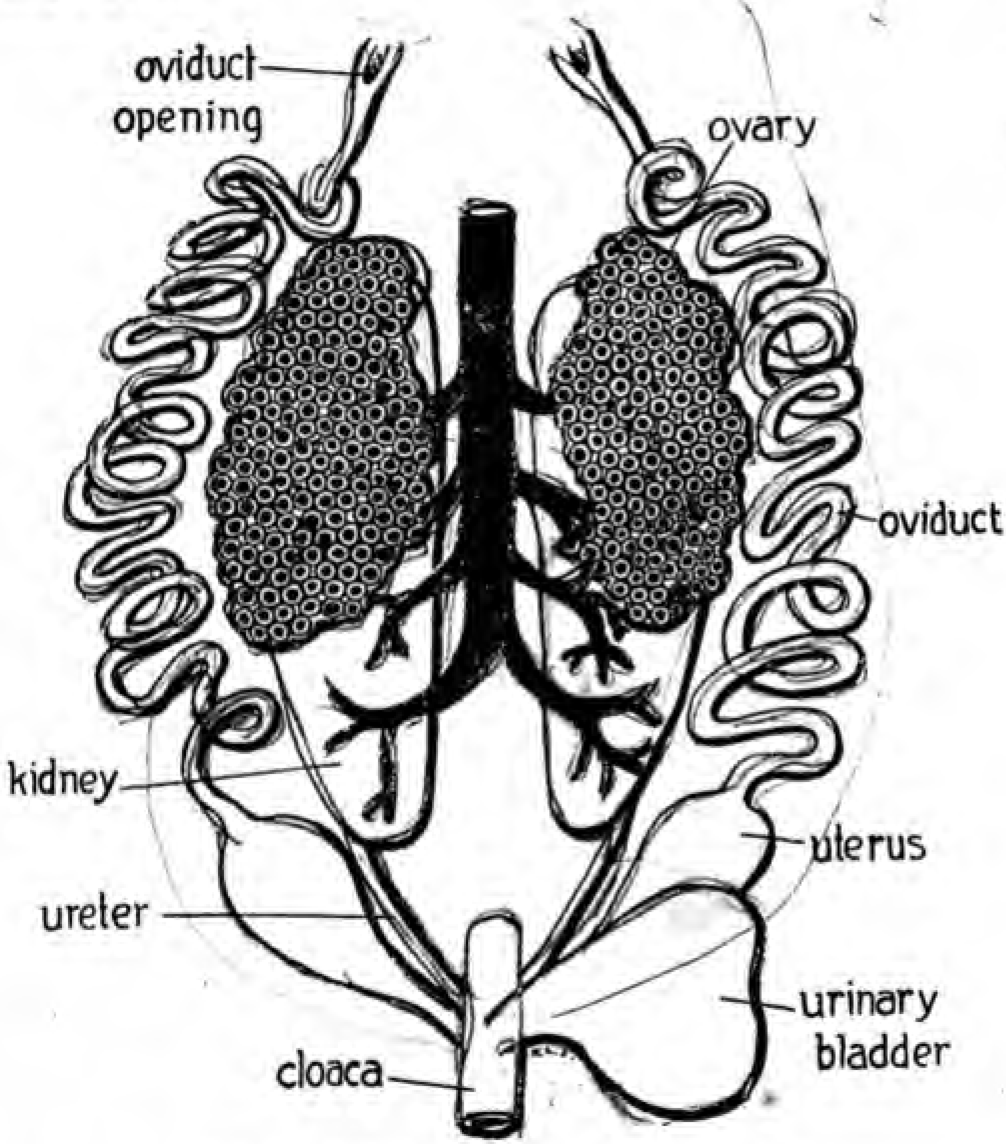


FIG. 71. Reproductive organs of the female frog.

The Female reproductive organs.—The gonads in the female frog are a pair of ***ovaries***, in which the ***ova*** or eggs are produced. The ovaries are large during the breeding season but insignificant at other times. Each ovary is an irregularly lobed sac, filled with black and white spherical ova,

There are no ducts connected to the ovaries. When the ova are ripe, the ovary ruptures and the ova escape into the body cavity. From the body cavity they reach the outside by a pair of much convoluted ***oviducts***, which have funnel-shaped mouth for the entry of the ova near the lungs. Posteriorly, the oviducts enlarge to form the so-called ***uterus***. The two uteri open close together into the cloaca in front of the openings of the ureters. As the ova pass down the convoluted oviduct the wall of this duct secretes a jelly-like covering for them. The eggs are temporarily stored in the uteri but the embryo does not develop in them. At the time of mating, the ova pass out into the water through the cloacal aperture. The cloaca thus serves not only for the passage of faeces and urine but also of ova and sperms.

RESUMÉ

Bionomics

1. Except in deserts and in the sea, frogs are widely distributed all over the world.

2. They are backboned animals belonging to the class Amphibia and family Ranidae. The common Indian frog is *Rana tigrina*.

3. Although a frog can live both on land and in water, yet it is incapable of living wholly in either medium.

4. It can tide over unfavourable conditions of weather by aestivating or by hibernating.

External morphology

5. Its body is bilaterally symmetrical.

6. The important external features of the frog are the flattened body, the bulging eyes, slimy and moist skin and the powerful hindlegs with webbed toes.

7. There are no scales, feathers, hairs or external 'ear' as in higher animals. There is no tail.

8. The male has resonating vocal sacs to serve as "loud-speakers". During the breeding season his thumb swells up enormously.

9. The body of the frog consists of several complex organ systems, each of which is specialized for a particular function.

Internal morphology

10. The alimentary system of the frog begins in the mouth and ends in the cloacal opening. It consists of the buccal cavity, pharynx, oesophagus, stomach, intestine and cloaca.

11. The tongue is the most conspicuous and important organ in the buccal cavity. It is attached in front but free behind, so that it can be shot out to capture the prey.

12. The frog does not possess salivary glands but there are mucous glands in the buccal cavity.

13. The frog swallows the food whole and usually alive, the teeth being used merely to prevent the escape of the prey. The mucus serves to lubricate the food.

14. Digestion begins only in the stomach, where the proteids are partly reduced by the gastric juice (containing hydrochloric acid and pepsin) to peptones and proteoses.

15. The digestion of proteids is completed in the intestine by the action of trypsin of the pancreatic juice and erepsin of the intestinal juice. The end-products of protein digestion are amino acids.

16 Fats are emulsified by the bile produced by liver and are then converted by lipase of the pancreatic juice to colloidal soaps and glycerol.

17. Water and minerals do not need any digestion.

18. The digested part of the food is absorbed in the intestine by the blood and lymph. The undigested matter passes into the large intestine and is ejected as faeces through the cloacal opening.

19. The liver is not a digestive gland but it is closely associated with the alimentary canal. It performs the following functions :

(*i*) *Helps digestion by secreting bile, which is in the nature of a waste product, and*

(a) Neutralizes the acidity of chyme

(b) Emulsifies fats

(c) Stimulates peristalsis and

(d) Acts as antiseptic on the contents of the intestine

(*ii*) *Helps metabolism by*

(*a*) De-aminising the amino acids of protein digestion

(*b*) Removing urea

(*c*) Producing glycogen and

(*d*) Destroying old blood cells.

(*iii*) *Helps excretion by*

(*a*) Separating urea

(*b*) Eliminating toxic substances from the blood and

(*c*) Destroying old corpuscles.

20. The absorbed food is used in

(*i*) Counter-balancing the loss of material

(*ii*) Rebuilding

(*iii*) Growth

(*iv*) Energy-production and

(*v*) As reserve store for future use.

21. The circulatory system serves for transporation of material.

22. The blood contains nucleated erythrocytes and leucocytes in plasma.

23. It is pumped by a three-chambered heart in a closed system of vessels.

24. Arteries convey blood from the heart and include the carotids, systemic and pulmonary trunks.

25. Veins return the blood to heart and include two precavals and a postcaval.

26. In addition to the long or systemic circulation the frog possesses three short circulations, viz. pulmonary, hepatic and renal portal

27. The lungs are the chief respiratory organs. They are alternately filled and emptied of air by force-pump-like action of the buccal cavity.

28. The kidneys are the excretory organs. They are made of knots of blood capillaries surrounded by a capsule that filters off the urine.

29. The ducts that carry the sperm from the testes pass through the kidneys. The ureters serve for conducting urine and sperm.

30. The ovaries are not connected to the oviducts. The latter open into the cloaca.

CHAPTER IV

THE FROG (*Continued*)

8. SKELETAL SYSTEM

What is skeletal system. The skeleton forms the framework of the body. It gives a definite shape to the animal. It affords support and protection to the softer internal organs and also gives attachment to the

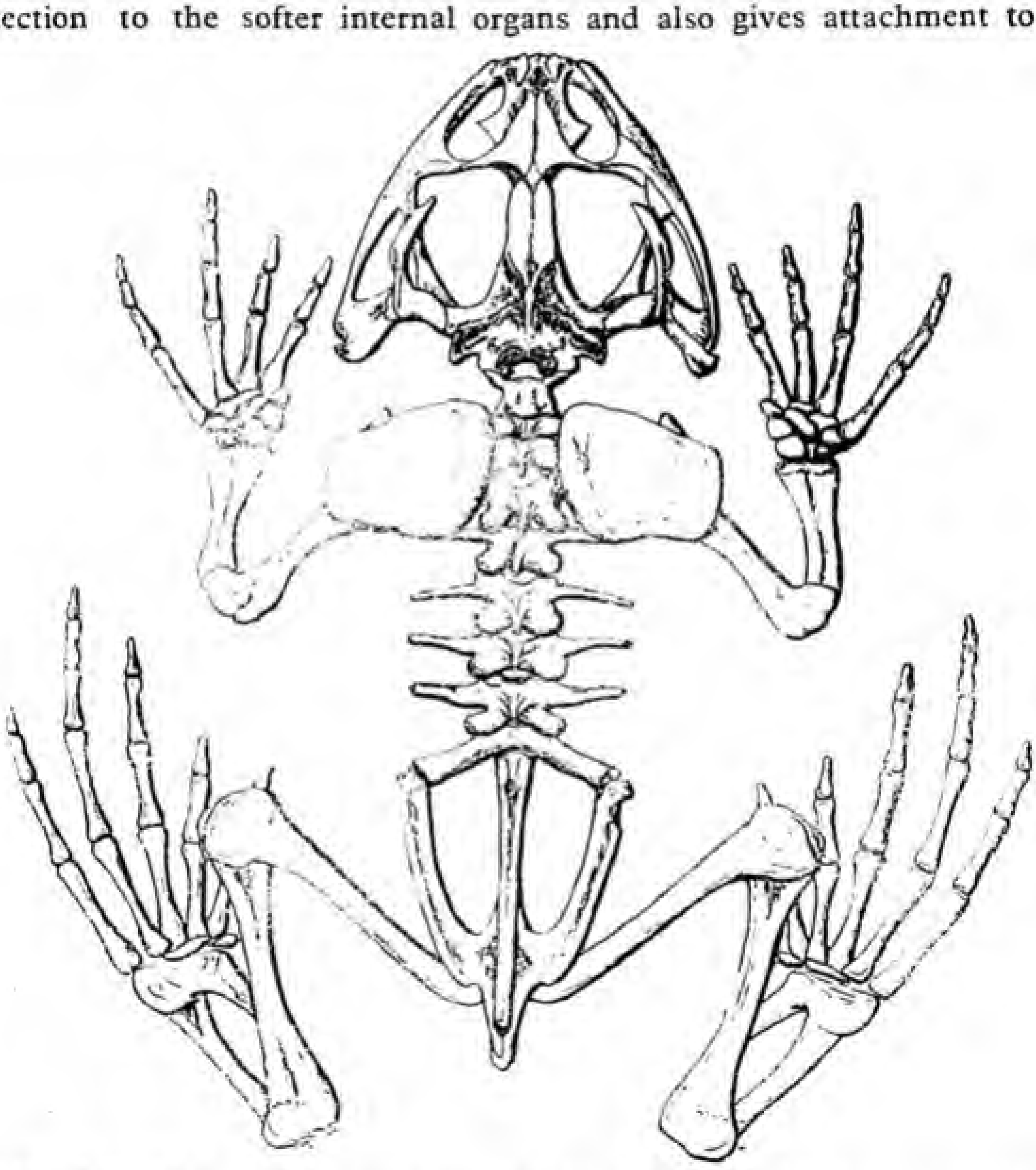


FIG. 72. Skeleton of the frog in dorsal view in the resting posture. The skeleton forms the framework of the body and gives a definite shape to the animal. The axial portion of the skeleton comprises the skull and the vertebral column and the appendicular portion comprises the limbs and the girdles. (*From a skeleton mounted by Mr. Viswanath Sinha, Zoology Museum, St. John's College, Agra*).

muscles. The skeletal elements are joined in a system of levers and thus enable movements of parts of the body and locomotion of the animal.

The skeletal system of the frog.—The skeletal system of the frog is composed of 1. cartilages, 2. calcified cartilages and 3. bones. A ***cartilage*** is an elastic skeletal structure. It may be twisted and bent but recovers its shape when freed. Many cartilages of the frog's skeleton get a deposit of lime and are then called ***calcified cartilages***. Other cartilages are replaced by ***bones***. Bones are also formed from connective tissue or dermal membranes. These are called ***dermal*** or ***membrane bones***, in contradistinction to those formed first as cartilages and then ossified into bones.

Bones consist of inorganic and organic parts. If a piece of bone is treated with a dilute acid, the inorganic portion dissolves in the acid, leaving behind a flexible tough model of organic matter. When this residual tough matter is boiled, ***gelatin*** or ***glue*** is obtained. When a piece of bone is burnt, the organic part disappears, leaving behind a friable earthy mass, consisting mainly of phosphates of calcium and traces of fluoride and carbonate of calcium. Many of the long bones are hollow, the cavity being filled with a red ***bone marrow***, in which the red corpuscles of the blood are manufactured.

The bones are joined together by connective tissue in such a way as to allow free movement at ***articulations*** or ***joints***. The bones in the skull are usually immovably jointed together by ***sutures***. Some bones, for example those of the backbone, are articulated with each other permitting limited movements. In a joint, the apposed surfaces of the bones are accurately modelled in relation to one another and are covered by cartilages to act as shock-absorbing cushions. There is also a lubricating fluid, the ***synovia***, between movable joints of bones.

Parts of the skeletal system of the frog

The skeletal system of the frog comprises an ***axial skeleton***, lying in the median longitudinal axis of the body, and an ***appendicular skeleton***, constituting the skeleton of the appendages or limbs.

Axial skeleton.—The axial skeleton of the frog comprises the ***vertebral column*** or the backbone and the ***skull***. A frog has no ribs. The breastbone is considered with the limbs.

Vertebral column.—The vertebral column of the frog consists of ten bones : nine ring-like bones, the ***vertebrae***, and a terminal rod-shaped ***urostyle***. The vertebral column supports the body, connects to the head

and limbs and forms a protective covering for the ***spinal*** cord (nerve cord). It is scarcely flexible in the frog.

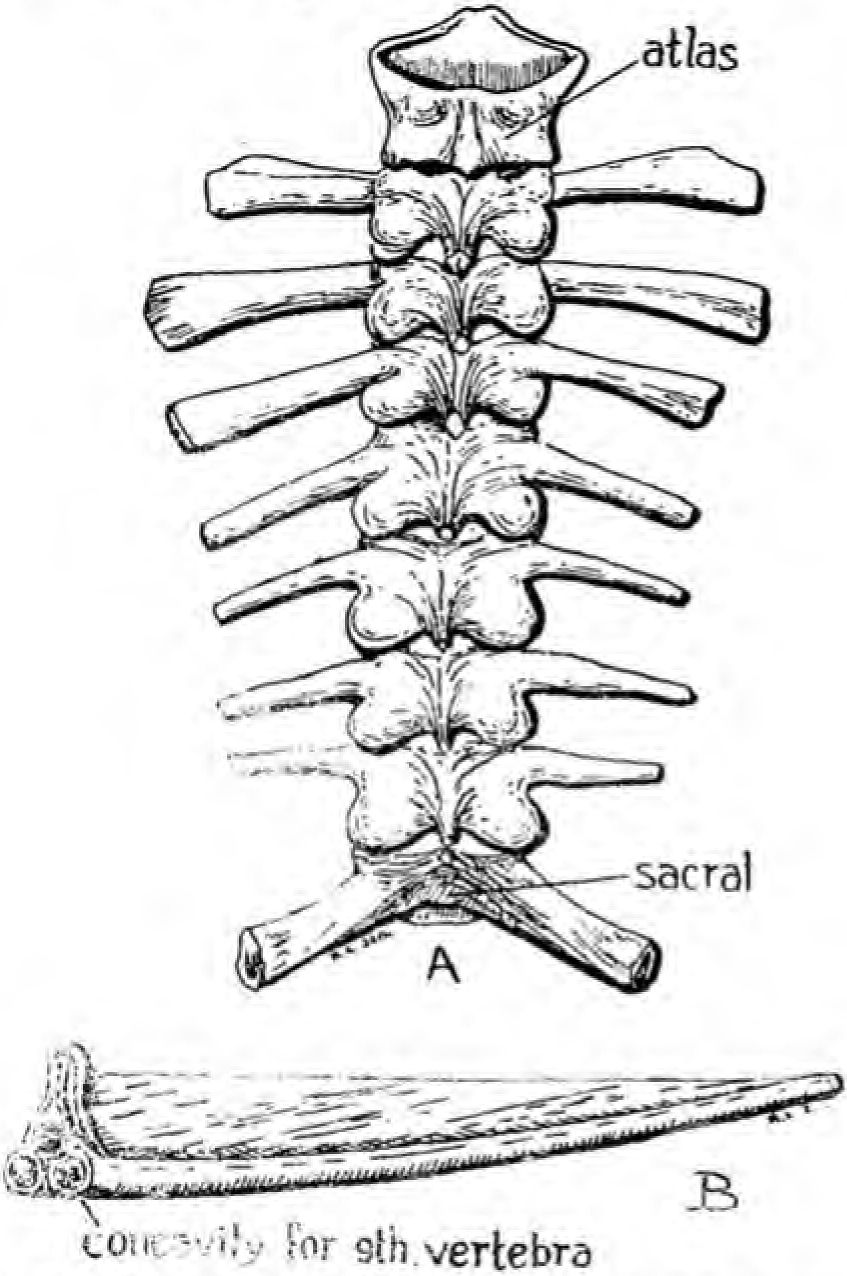


FIG. 73. Part of the axial skeleton of frog. A. Vertebral column in dorsal view, B. Urostyle in lateral view, with the anterior end on the left. It represents a number of fused caudal vertebrae.

The first and the ninth vertebrae differ markedly from the rest. Any of the remaining vertebrae may be considered as a typical one. A typical vertebra consists of a short subcylindrical body, the ***centrum***, below. On the dorsal surface of the centrum there is a flat bony arch, the ***neural arch***, enclosing a hollow space the ***neural canal***, through which the nerve cord passes.

Except in the first, eighth, and the ninth vertebrae, the centra of the rest have a ball-like knob posteriorly and a corresponding concave depression

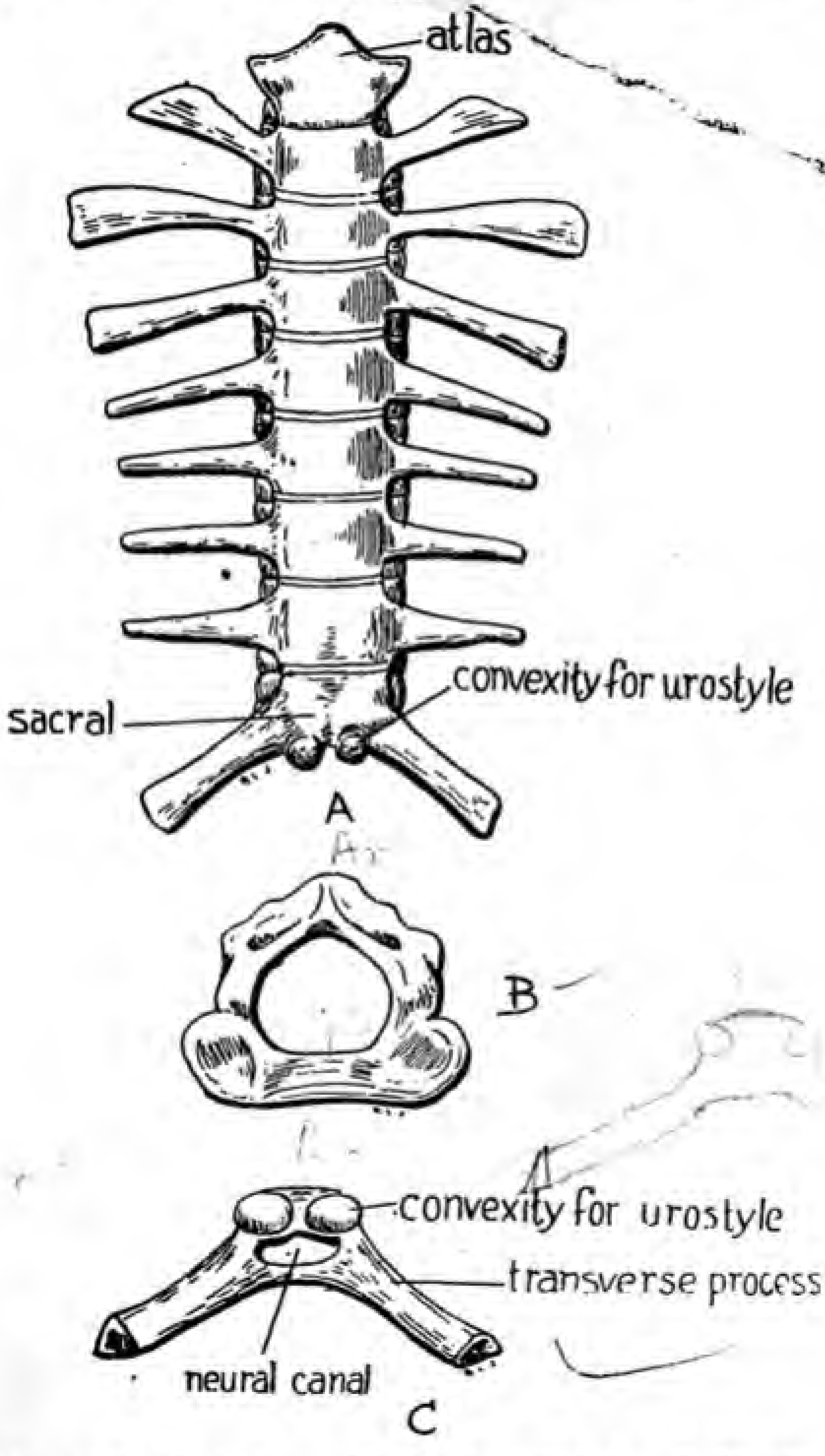


FIG. 74. A. Vertebral column of the frog in ventral view. B The atlas vertebra in anterior view. The skull articulates with it. C. The sacral vertebra in posterior view. The urostyle articulates with it.

anteriorly. The posterior convexity of a vertebra fits into the anterior concavity of the centrum of the next vertebra. The centrum of the eighth vertebra is concave at both ends. The centrum of the ninth vertebra is convex anteriorly. Posteriorly, it has two small convex processes which fit into corresponding concave pits in the anterior ends of the ***urostyle***. A vertebra with the centrum concave in front is described as ***procoelous***. On cutting across the centrum into two, the remnant of an elastic ***notochord*** or ***chorda dorsalis*** is revealed. The notochord is the primordial axial skeletal rod, round which the vertebral column develops later. The notochord occurs in all Chordata. The neural arches of vertebrae are joined together by articulating facets called ***zygapophyses***. The anterior zygapophysis is directed inward and upward, and the posterior zygapophysis is pointed outward and downward. The neural arch of each vertebra bears dorsally a backwardly directed ***spinous process*** or ***neural spine***. The neural spines of the third, fourth and fifth vertebrae are the largest and that of the ninth is practically absent. The neural arches have lateral broad, flat, projecting bony pieces called ***transverse processes***. The transverse processes and the neural spines of the vertebrae serve for the attachment of muscles of the trunk.

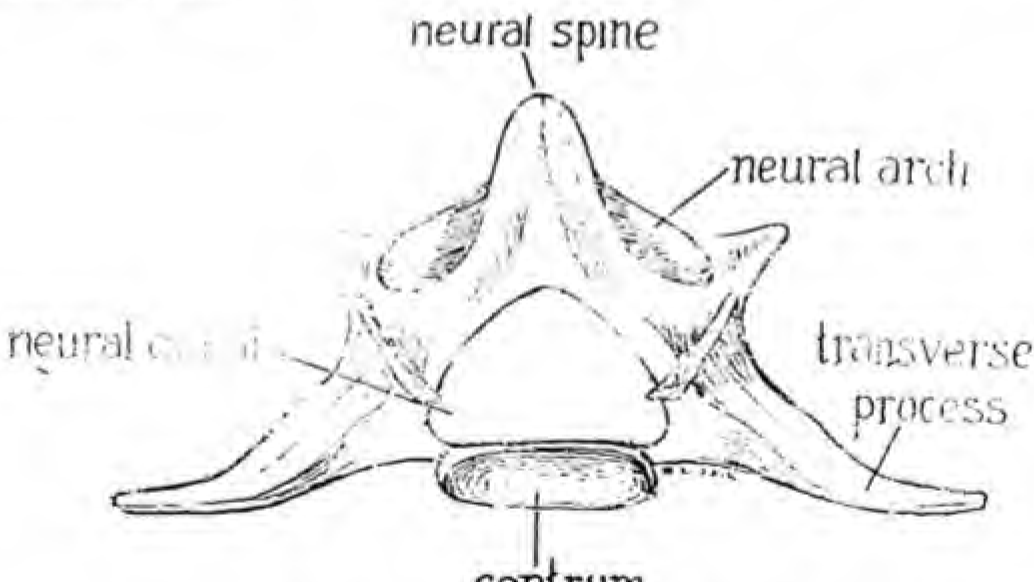


FIG. 7.5. A typical vertebra of the frog in anterior view.

The transverse processes do not all stand at right angles to the vertebral column but often point in various directions. The fourth vertebra has the longest transverse process and the seventh and the eight have the shortest. The transverse processes of the second and third vertebrae point

outward and downward ; those of the fourth, fifth and sixth point upward and backward.

The first vertebra is called ***atlas***, because in man this vertebra bears the entire weight of the skull. The atlas of the frog has a very thin centrum and a rather wide ring-like neural arch. Posteriorly the centrum bears a broad articular head. Anteriorly there are two oval concave articular surfaces, separated by a median projection. These concavities receive

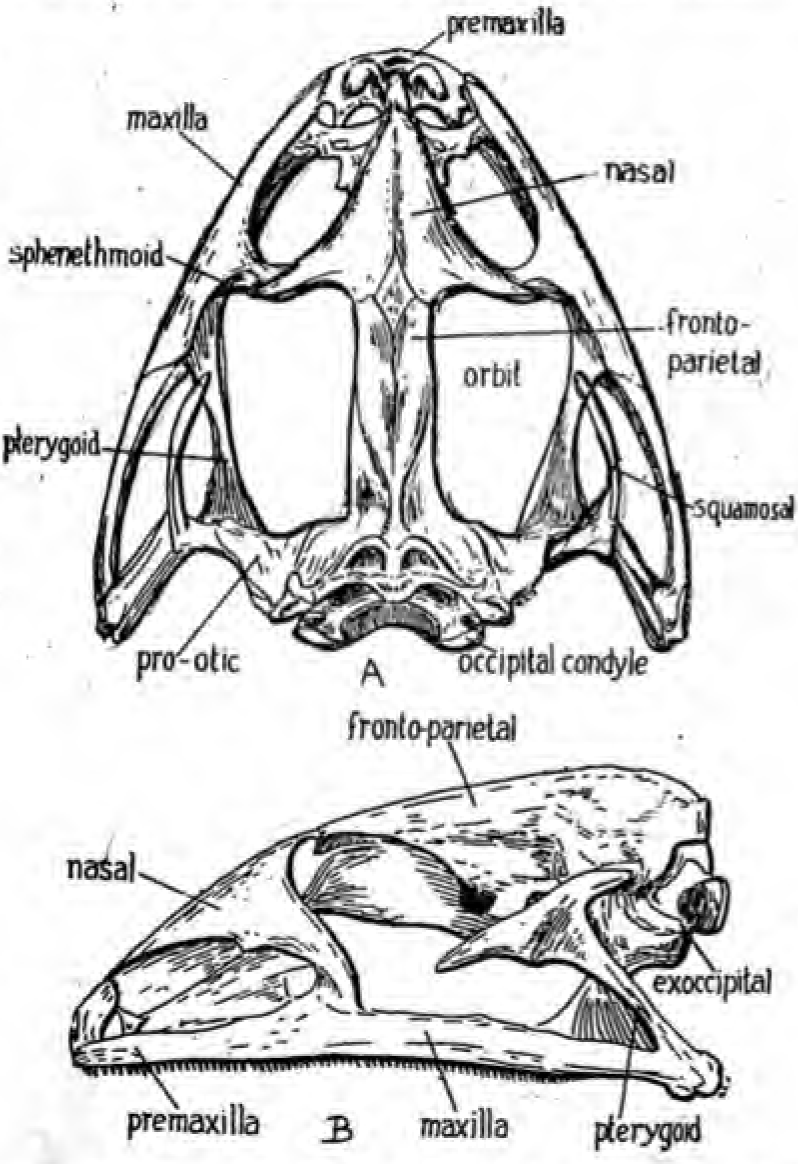


FIG. 76. Skull of the frog. A. Dorsal view. B. Lateral view.

the articulating ***condyles*** of the skull. The atlas has *no* transverse processes.

The ninth or the ***sacral vertebra*** unites the vertebral column with

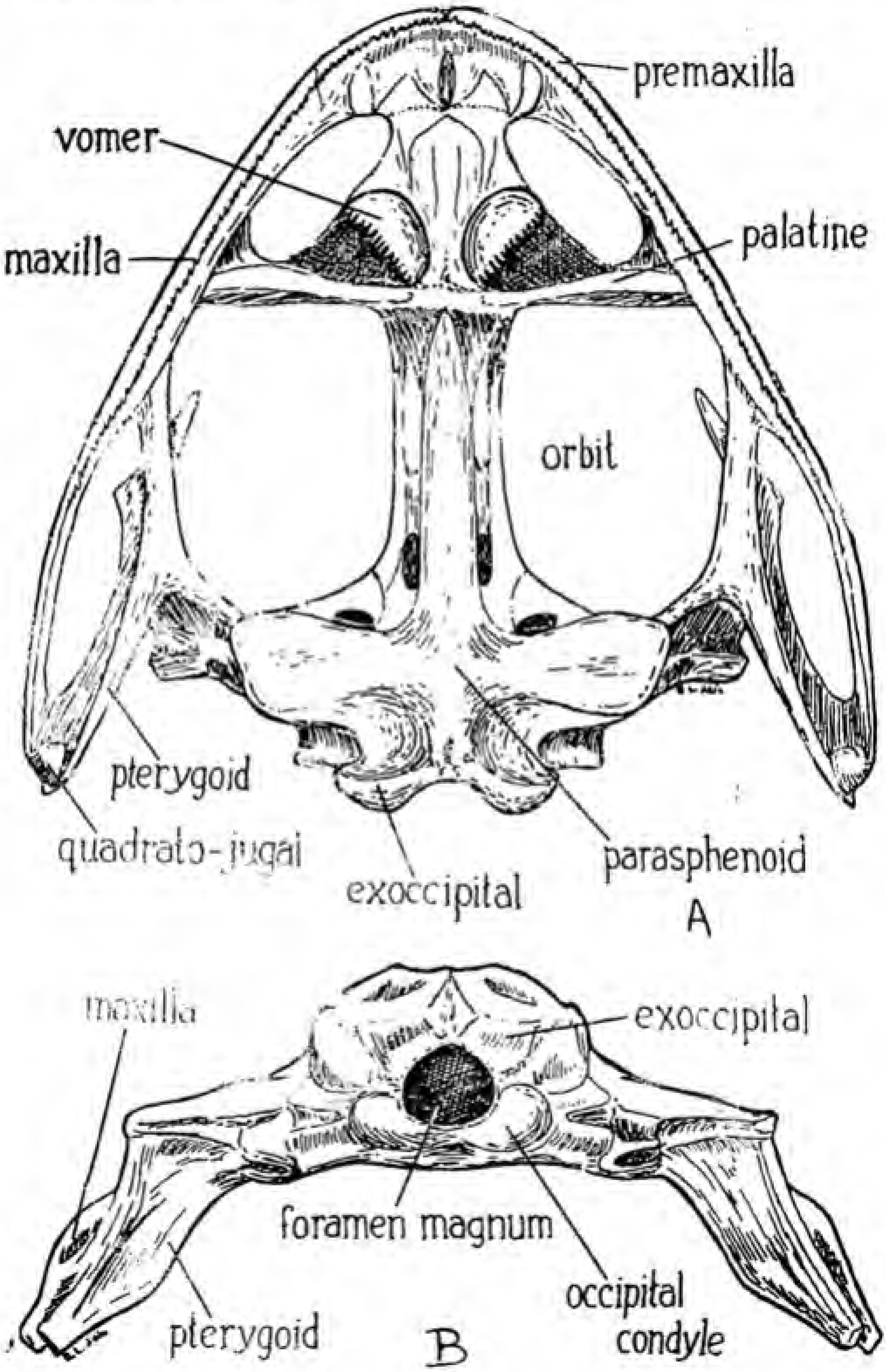


FIG. 77. Skull of the frog. A. Ventral view. B. Posterior view

the hip bones. The centrum is anteriorly convex and posteriorly has two

small knob-like convexities, close to each other, for articulation with the urostyle. The transverse processes are strong, broad and pointed dorsally and posteriorly.

The urostyle is the last part of the vertebral column. It is nearly as long as the rest of the column. It is believed to be composed of a number of fused vertebrae. It is a rod-like bone with a raised ridge dorsally. It is thicker and higher anteriorly than behind. In the anterior end there are two concave depressions which fit into the corresponding convexities of the sacral vertebra. The urostyle is hollow anteriorly and encloses the terminal part of the nerve cord.

The skull.—The skull is composed of bones and cartilages. It is articulated to the atlas vertebra by two prominent convex facets, the ***occipital condyles***. The skull is large, flat and triangular and consists mostly of the massive and wide jaws and the large orbits or the cavities for the eyes. It comprises 1. a relatively small ***cranium*** or the brain-box proper 2. to which the upper jaw bones are immovably and the lower jaw bones movably articulated, 3. the paired ***sense capsules*** *viz.* the ***olfactory*** or the nasal capsule, the orbit or ***optic*** capsule and the auditory or the ***otic*** capsule and 4. the ***hyoid*** or the tongue bone.

The cranium.—The cranium is a thin tube, partly cartilagenous and partly bony, wider behind than in front. It encloses the brain within. Posteriorly the cranium presents a large aperture, the ***foramen magnum***, through which the spinal cord within the vertebral column passes to the brain.

Bones of the cranium.—The foramen magnum is bounded laterally by the ***exoccipital bones***, which bear the ***occipital condyles***. Above and below the foramen magnum, the exoccipitals are separated by cartilages. The anterior part of the cranium is completed by the ***sphenethmoid bone***. This bone is ring-like posteriorly and encloses a cavity, in which the anterior part of the brain is lodged. Anteriorly the sphenethmoid is divided by a median vertical partition into a double chamber, in which the olfactory capsules are lodged. The middle part of the cranium is cartilagenous, but the cartilage is covered by membrane bones. The roof of the cranium from the exoccipital to the sphenethmoid is completed by a pair of ***fronto-parietal*** bones. These are flat long bones united immovably by a suture in the middle and covering the cartilagenous part of the cranium underneath. They just overlap the sphenethmoid in front. Laterally the outer margins of the frontoparietals are curved down. In front of the frontoparietals there is a pair of subtriangular ***nasal bones***, roofing the cartilage of the olfactory

capsule. Ventrally below the cartilagenous floor of the skull, there is a dagger-

FIG. 78. Frontoparietal of the frog in dorsal view.

shaped ***parasphenoid***. The floor of the nasal capsule is supported by a pair of ***vomers***, which bear the vomerine teeth.

FIG. 79 Squamosal of the frog.

Posteriorly on either side of the cranium are the auditory capsules. The anterior and ventral sides of these capsules are completed by the ***pro-***

otic bones. The pro-otic bones lie at the sides and in front of the ex-occipitals. They protect the organs of hearing.

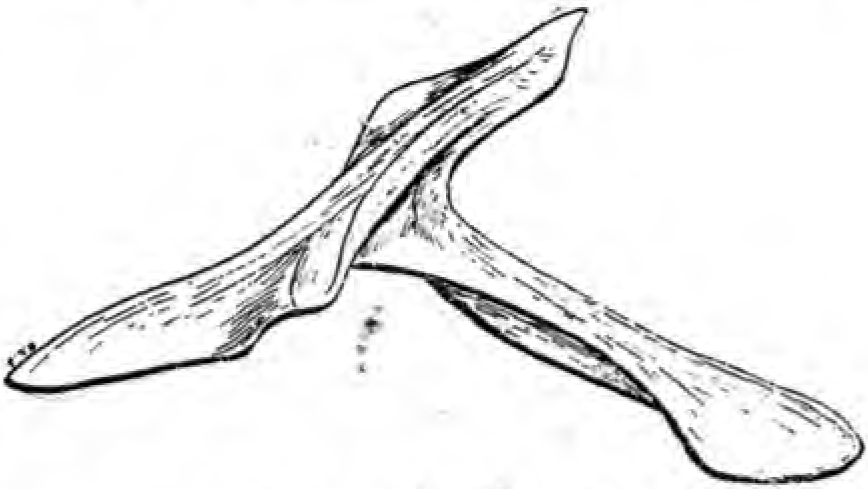


Fig. 80. Pterygoid of the frog.

The upper jaw bones.--The upper jaw has a pair of ***premaxilla*** in front and a pair of ***maxilla*** behind. The two premaxillæ are united

Fig. 81. Parasphenoid of the frog in ventral view.

in front and bear marginal row of teeth. The maxillæ are elongated, curved bones, broad in front and narrow behind and also bear teeth

below. The anterior end of the maxilla articulates with the premaxilla and the posterior end with the ***quadratojugal***. A transverse pair

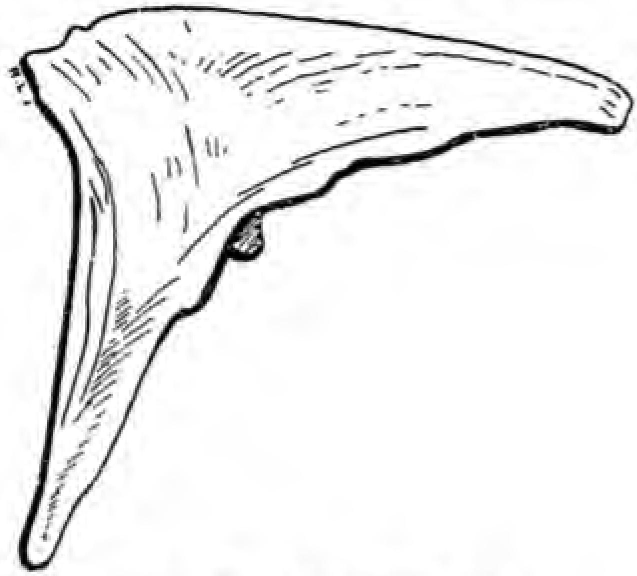


FIG. 82. Nasal of the frog.

of slender ***palatine*** bones connect the anterior end of maxilla with the sphenethmoid. A triradiate or Y-shaped bone, the ***pterygoid***, reaches from the point where the palatine unites with the maxilla to the pro-otic. The posterior outer arm of the pterygoid is covered by the small ***quadrate*** cartilage, which gives articulation externally of the lower jaw. Above the quadrate lies a T-shaped ***squamosal*** or the ***suspensorium***.

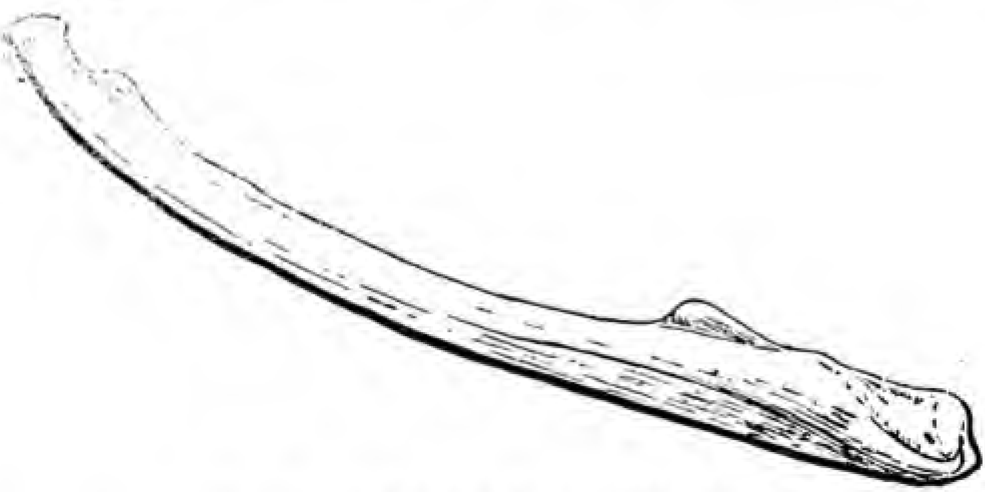


FIG 83. Left half of the mandible of frog.

The lower jaw or the ***mandible*** consists of two bony arches united anteriorly by ligament in the middle. Each arch is composed

of 1. a ***Meckel's cartilage,*** 2. a ***mentomeckelian*** bone, covered by

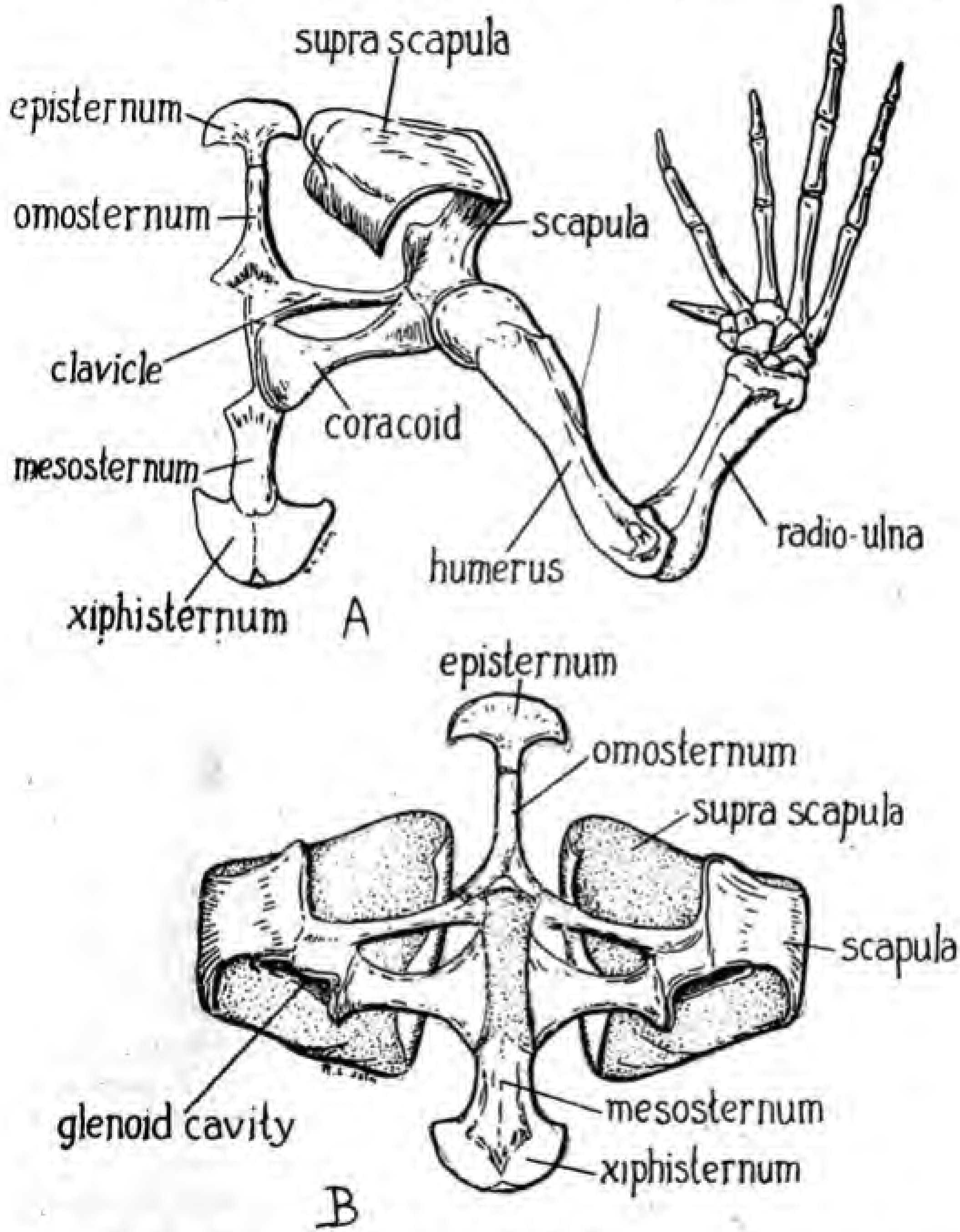


FIG. 84 A. Dorsal view of the right of half of the pectoral girdle, the sternum and the right fore leg of the frog. B. The complete pectoral girdle with the sternum in ventral view.

3. ***angulosplenial*** inside and below, and 4. a ***dentary*** above and outside. The angulosplenial expands posteriorly and forms the head

for articulating with the *glenoid* cavity formed posteriorly by the pterygoid, quadrate and the squamosal.

The appendicular skeleton.—The appendicular skeleton is divisible into an anterior and a posterior part. Each of these again comprises a proximal *girdle* and a distal *free extremity*. The anterior girdle is called *pectoral* or shoulder girdle, to which the *anterior extremities* or the bones of the fore limbs are attached. The posterior girdle is called the *pelvic* or the hip girdle ; the hind legs are attached to this.

The pectoral girdle.—The pectoral girdle is composed of bones, cartilages and calcified cartilages It is intimately and rigidly connected ventrally to the *sternum* or the breastbone. Dorsally it is not directly articulated to the vertebral column but is connected with it by muscles. It thus girdles or loosely encircles the anterior part of the body and encloses the heart and lungs. It also serves as a support for the weight and absorbs shocks, when the frog jumps and lands on the ground. It acts as a place of attachment for the fore legs, and for the numerous muscles of the trunk.

Each side of the pectoral girdle is composed of four elements : two above an irregular hollow *glenoid* cavity and two below. Dorsally overlapping the first four vertebrae is the broad, flat, trapezium-shaped calcified cartilage called *suprascapula* It is articulated outward and below with a flat, four-cornered bone, the *scapula* or shoulder blade. The outer ventral margin of scapula borders half the glenoid cavity In the lower half there is a large stout bone, the *coracoid.* It is expanded at its ends, but more so at the inner end. The outer end articulates with the scapula. The inner ends of the coracoids of the right and left sides do not meet in the mid-ventral line but are separated by the *epicoracoid* cartilage. In front of the coracoid is the *precoracoid cartilage*, which connects the scapula and the epicoracoid. The cartilagenous rod is ensheathed by a bone, the *clavicle* or the collarbone.

Sternum.—The sternum or breastbone lies in the midventral line. The lower ends of pectoral girdle are articulated with it. It consists of 1. an *episternum*, a flat semicircular plate of cartilage ; 2. an *omosternum* a bony rod ; and 3. a *mesosternum*, a rod of cartilage ensheathed in bone ; and 4. a broad and often bilobed calcified cartilage, the *xiphisternum*. Between the omosternum and mesosternum lie the epicoracoids of the pectoral girdle.

Bones for the fore limb—The upper arm bone is called ***humerus***. It has a shaft and two articular surfaces, one at each end covered by

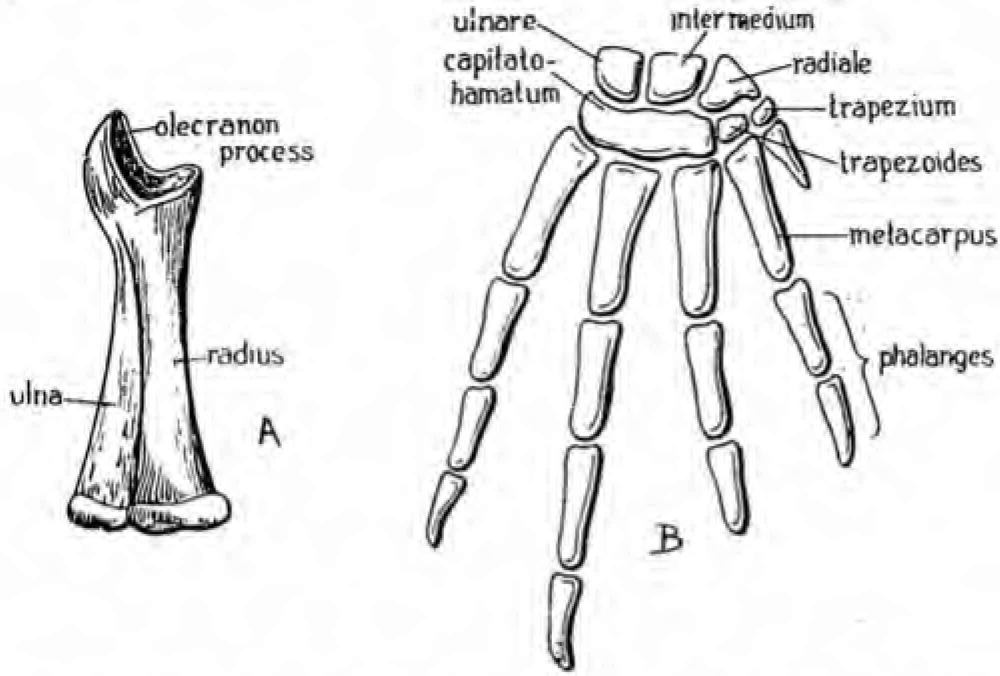


FIG. 85 Appendicular skeleton of the frog. A. Radio ulna. B. Bones of the wrist, palm and fingers of the fore limb.

cartilage. The proximal articular surface is the ***head*** of the humerus and it fits into the glenoid cavity of the pectoral girdle The glenoid cavity and the head of the humerus thus form a ball-and-socket joint, allowing swinging movement of the fore limbs. In the upper half ventrally on the outer side there is a prominent crest called the ***deltoid ridge***, to which the deltoid muscle is attached The distal end has a rounded knob, with an ***internal*** and an ***external*** condyle on either side. The lower arm has two bones, the ***radius*** and ***ulna*** fused firmly and immovably the whole of their length to form a compound bone called ***radio-ulna***. The proximal end of the radio-ulna has a large concavity for articulating with the knob at the distal end of humerus. Beyond the concavity, the ulnar part of the radio-ulna continues as a hook-like ***olecranon*** process that forms the elbow. Distally there are two articular facets respectively of the radial and of the ulnar parts. In man also the lower arm has these two bones but they are separate. The ulna takes the main articulation with the humerus and the radius with the wrist. The latter bone can be crossed over the former, carrying the wrist with it and thus turn the palm

downwards. In the frog these two bones are fused half way to crossing. The frog cannot turn its palm upwards.

There are six small bones in the ***carpus*** or wrist of the frog, arranged in a proximal and a distal row. The proximal row comprises a ***radiale*** and an ***ulnare***, with an ***intermedium*** in between. In the distal row there is on the ulnar side a large crescentic ***capitatohamatum***, which articulates with all three bones of the proximal row. On the radial side there are two small bones, *viz.* the ***trapezium*** and the ***trapezoid***. In the hand there are five proximal ***metacarpals***, which are joined to the wrist. The metacarpals are succeeded by the ***phalanges*** or the bones of the fingers. The fourth and the fifth fingers have each three phalanges, the second and the third have each two. The first or the ***polex*** has no phalanges but ends in a metacarpal.

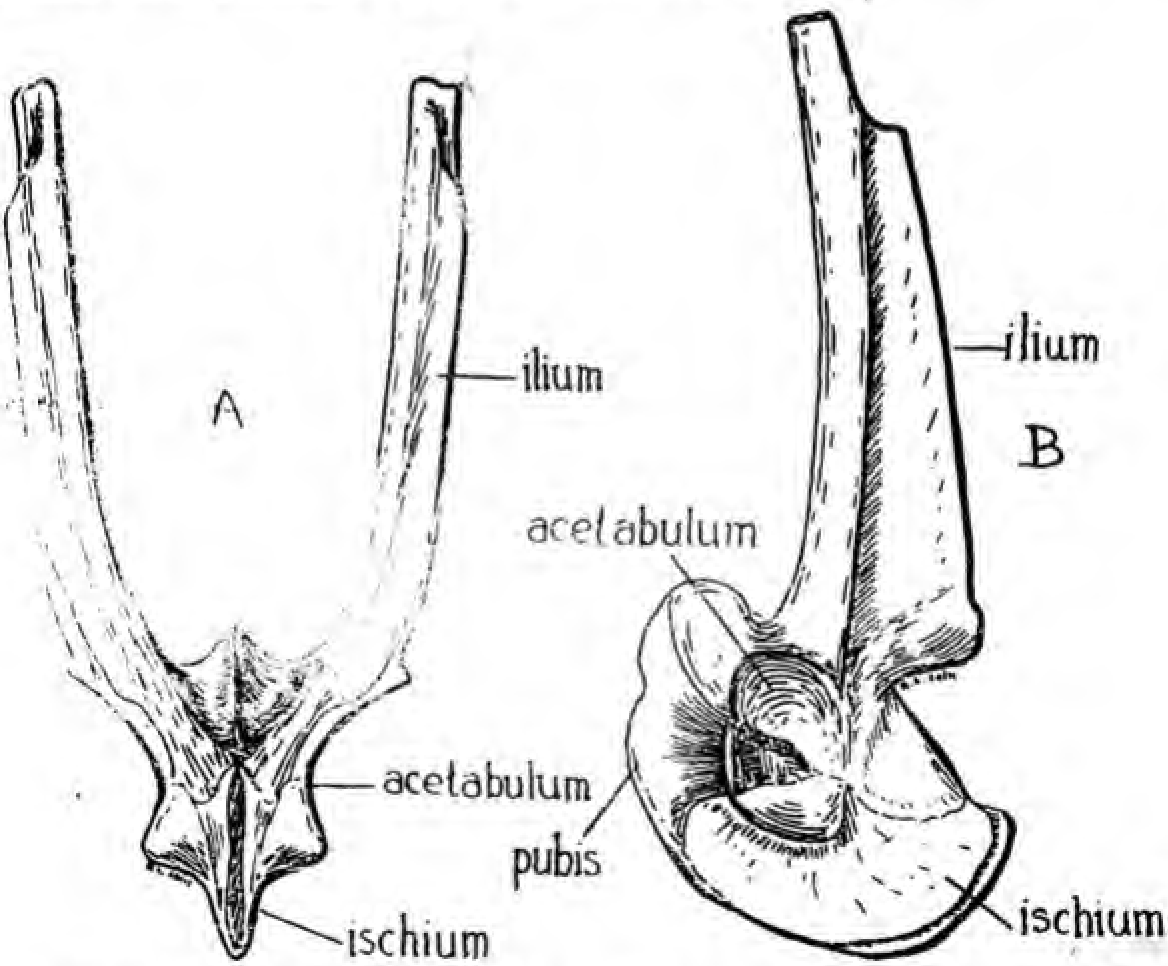


FIG. 86. The pelvic girdle of the frog. A. Dorsal view. B. Lateral view.

The pelvic girdle.—The pelvic girdle differs from the pectoral girdle in being directly articulated to the transverse processes of the ninth

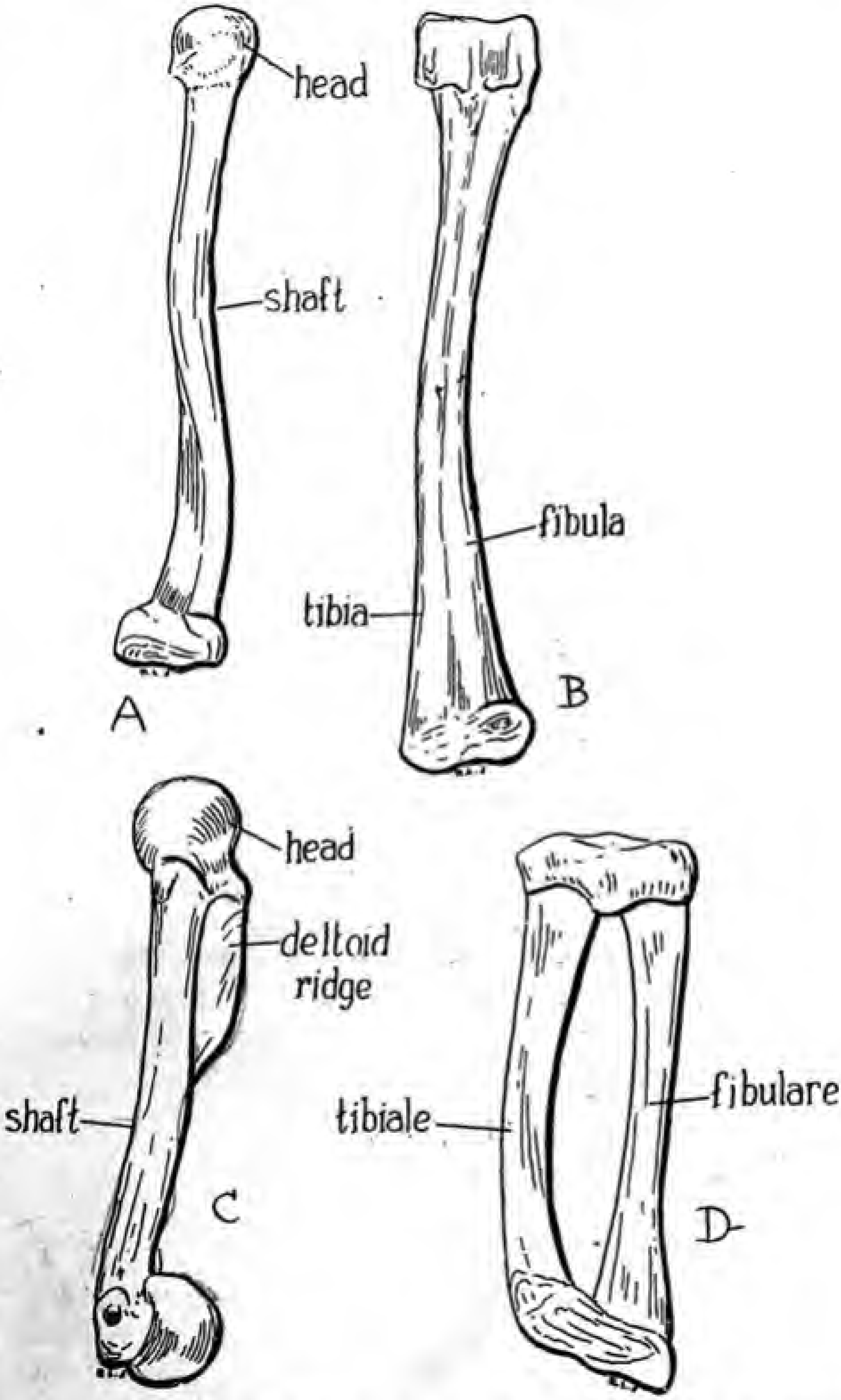


FIG. 87. Appendicular skeleton of the frog. A Femur. B. Tibiofibula. C. Humerus. D. Astragalus (tibiale) and calcaneum (fibulare).

vertebra. It has the shape of an elongated V and comprises three elements : ***ilium, ischium*** and ***pubes***. The ilia are a pair of long slender bones, articulated anteriorly to the transverse processes of the sacral vertebra and posteriorly with the ischium and pubes. The external surface of the posterior part of ilia form half the ***acetabulum***, or the articular concavity for the leg. The acetabulum is completed by ischium behind and pubes below.

Bones of the hindleg.—The ***femur*** or the thigh bone is a long cylindrical bone resembling an elongated S. The proximal end has a rounded cartilagenous articular head, which fits into the acetabulum. The distal end has a larger cartilagenous articular surface, flattened above and rounded below. The femur is articulated distally to the compound bone ***tibiofibula***. In man there are two separate bones, *viz.* tibia and fibula but in the frog these two are fused together. The proximal end of the tibiofibula is longitudinally grooved and the distal end is transversely elongated. The ***tarsus*** or ankle has a proximal and a distal set of bones. The proximal bones are the inner ***tibiale*** or ***astragalus*** or the ankle bone and the outer ***fibulare*** or ***calcaneum*** or the heel bone. The distal tarsals are two small calcified cartilages, the ***cuboid*** and the ***navicular***. There are six toes, the first being a reduced supplementary toe. The innermost of the remaining five is the ***hallux*** or the great toe. There are five long ***metatarsals*** for the five toes, succeeded by the ***phalanges***. The first and the secon toes have each two phalanges, the third and the fifth have each three, and fourth, which is the longest toe, has four phalanges.

Comparison of the fore and hind limbs : Tetrapod Plan of Limbs

The fore and hind limbs of the frog differ in the proportions of the parts but are built on essentially the same plan. They have corresponding bones :

FORE LIMB				
Upper arm	Lower arm	Wrist	Palm	Fingers
Humerus	*Radius* and *ulna* (fused)	*Carpals*	*Metacarpals*	*Phalanges*
HIND LIMB				
Thigh	Shin	Ankle	Sole	Toes
Femur	*Tibia* and *fibula* (fused)	*Tarsals*	*Metatarsals*	*Phalanges*

In both the cases the proximal segment has one bone. The humerus is analogous to the femur. The distal segment has two bones : the radio-ulna is analogous to the tibiofibula. The carpals have their counterparts in the tarsals ; the metacarpals and the phalanges agree with the metatarsals and phalanges. Paired structures like the fore

and hind limbs built of identical parts are described as ***serially homologous.***

Not only the fore and hind limbs of the frog are built on the same structural plan, but the limbs of all land Vertebrates like man, horse, bird and bat, are also built of the same identical bones. In other words the limbs of the tetrapod (four-footed) Vertebrates are

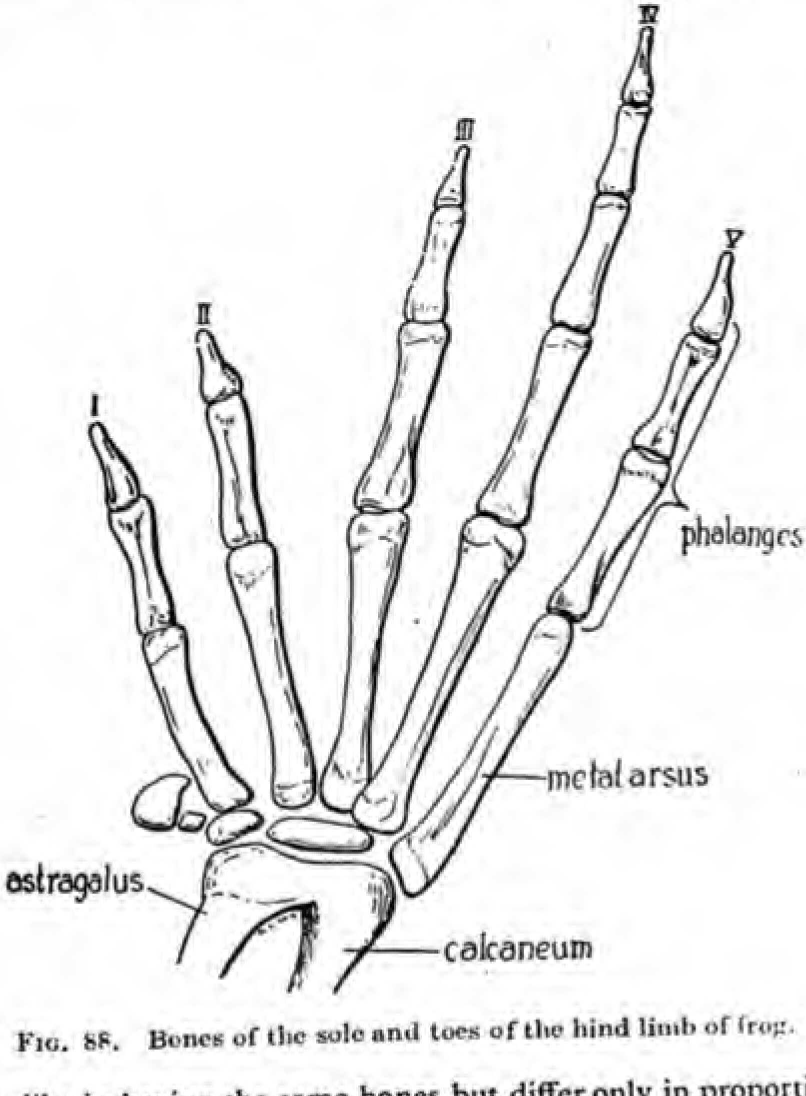


FIG. 88. Bones of the sole and toes of the hind limb of frog.

essentially alike in having the same bones but differ only in proportions of the different bones. Notwithstanding their specialization, the hands and feet of man have the same structural plan as that of the frog. In different animals the limbs are variously modified for jumping, walking, running or flying. Some animals stand on the sole of their feet, others on their toes and still others like the horse on the nails (hoofs) of their toes.

CONSPECTUS OF THE SKELETAL SYSTEM

I. Skeletal system is the framework of the body.

1. It is composed of
   (*a*) cartilage
   (*b*) calcified cartilage and
   (*c*) bone.
2. It is divisible into
   (*a*) axial skeleton and
   (*b*) appendicular skeleton.

II. Axial skeleton

1. Vertebral column
   Nine Vertebrae and urostyle
   First vertebra is atlas ; has no transverse process.
   Ninth vertebra is sacrum ; has two convex knobs posteriorly for the urostyle.
2. Skull
   (*a*) Cranium
   (*b*) Sense capsules
   (*c*) Jaws and
   (*d*) Hyoid.

III. Bones of the cranium

1. Exoccipitals, sphenethmoid, frontoparietals and parasphenoid.
2. Olfactory capsule : Nasal, vomer.
3. Optic capsule : pro-otic and
4. Upper jaw : Premaxilla, maxilla and quadratojugal attached to cranium by palatine, pterygoid, quadrate and squamosal.
   Lower jaw : Mentomeckelian, Meckel's cartilage, dentary and angulosplenial.

IV. Appendicular skeleton

1. Girdles and
2. Free extremities.
   (*a*) Pectoral girdle : Suprascapula and scapula above, Precoracoid, clavicle and coracoid below.
   (*b*) Pelvic girdle : Ilium, ischium and pubes

(c) Free extremities
Fore limb : humerus, radio-ulna, carpals, metacarpals and phalanges.
Hind limb : femur, tibiofibula, tarsals, metatarsals and phalanges.

9. MUSCULAR SYSTEM

Muscles.—Muscles, commonly also called "flesh", serve to bring about motion and locomotion. These movements are often the result of co-operation between the skeletal and muscular systems. The muscles

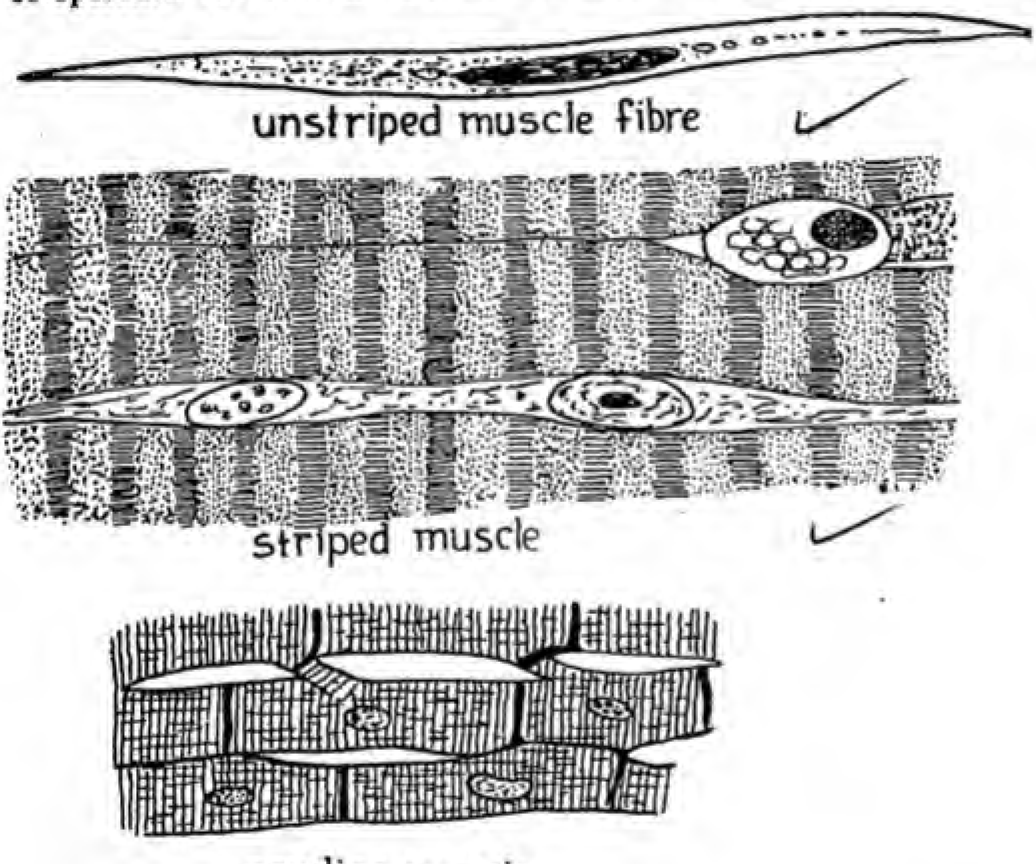


Fig. 89. Fibres of the three kinds of muscles of the frog.

effect this by "contracting", i. e., suddenly shortening in length but swelling up in thickness. They thus change their shape but not the volume when they contract. In order to be able to contract in an ideal manner, they consist of bundles of elongated fibre-like cells. Since muscles are usually attached by ***tendons*** at their two ends to bones, a contrac-

tion of the muscle causes a "pull" at one end. The fixed end is described as the point of ***origin*** of the muscle and the end which moves is the point of ***insertion.*** Muscles also serve to give the characteristic posture and attitude to animals. They cover and protect important internal organs.

Muscles are of three kinds: 1. ***smooth*** muscles, 2. ***striated*** muscles and 3. ***cardiac*** muscles. The smooth muscles are also called ***involuntary*** muscles, because they occur in the walls of such organs as stomach, intestine, etc., which are not under the control of the will power of the animal. The striated muscles are also called ***voluntary*** muscles, because they are under the control of the will. The fibres of these muscles appear transversely striated when viewed under a microscope. They are mostly the skeletal muscles that are attached to bones and produce movements and locomotion. The cardiac muscles belong to the heart and are also striated but are not under the control of the will.

Muscles never *push* but always *pull*. The bending of the arm for example is brought about by the contraction of the ***biceps*** muscle

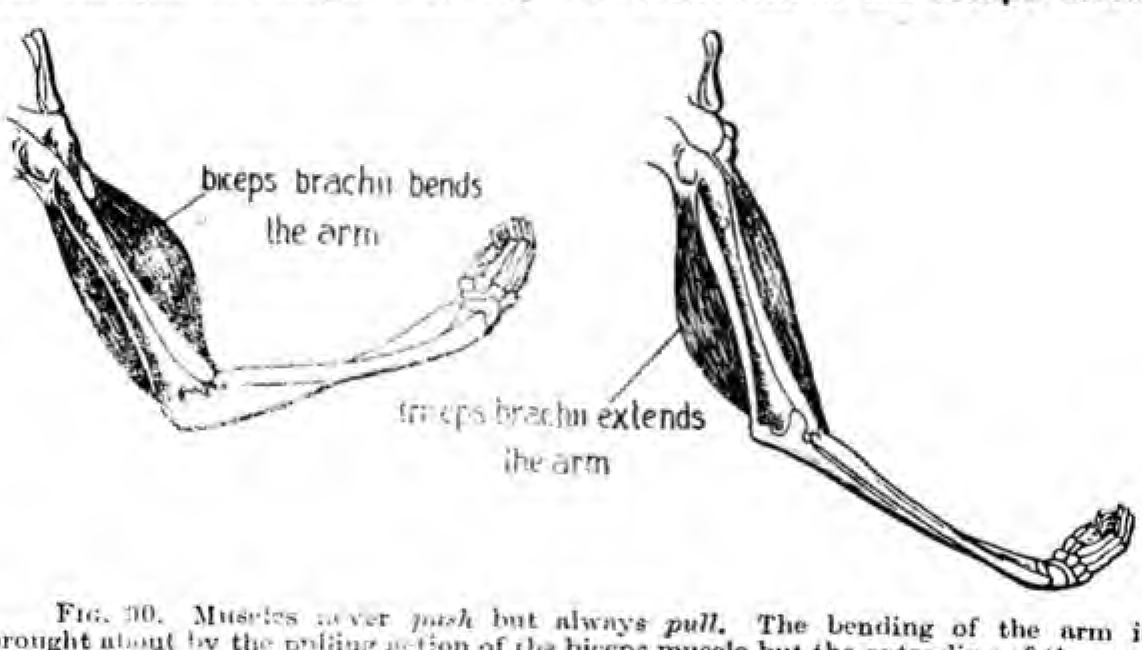


FIG. 90. Muscles never *push* but always ***pull.*** The bending of the arm is brought about by the pulling action of the biceps muscle but the extending of the arm is not caused by its pushing. Another muscle on the opposite side—the triceps—pulls the arm open.

on the inner surface of the upper arm (Fig. 90). The straightening of the arm is not caused by the relaxing and pushing of this muscle but by the contraction of another muscle on the opposite side. Muscles thus form *antagonistic* groups :

1. ***Flexor*** bends one part against another. Example: *biceps*, which bends the fore arm towards the upper arm.
   Extensor extends or straightens out the part bent by the flexor. Example: *triceps*, which straightens the fore arm.
2. ***Abductor*** moves a part away from the axis of the body. Example: the *deltoid* muscle which swings the foreleg outwards.
   Adductor pulls the part towards the body. Example: *latissimus dorsi*.
   Depressor lowers a part. Example: *mandibular depressor* opens the mouth by moving the lower jaw downward.
   Levator raises the part. Example: *masseter*, which closes the mouth by raising the lower jaw.
4. ***Rotator*** rotates a part. Often an inner and an antagonistic outer rotator present.
5. ***Constrictor*** constricts an opening. Example : *Sphincter* muscle which closes the anal opening.
   Dilator expands a circular opening.

Superficial muscles of the frog.—There are many hundreds of muscles in the body of the frog. The more important of these are shown in figure 91.

On the ventral surface of the head is the ***submaxillaris*** muscle, which forms the floor of the buccal cavity. It is important in swallowing food and in depressing the floor of the buccal cavity in respiratory movements. Dorsally on the head is the ***temporalis*** muscle. It takes its origin in the pro-otic bone, passes beneath the squamosal and is inserted on the angulo-splenial. When it contracts, it elevates the lower jaw. The ***deltoid*** muscle arises from the clavicle, precoracoid, omosternum and scapula and is inserted on the deltoid ridge of the humerus. Its contraction draws the fore limb forward. The ***biceps*** or the ***sternoradialis*** muscle arises from the omosternum and epicoracoid and is inserted on the radio-ulna. Its contraction bends the fore arm. The ***triceps brachii*** extends the fore arm. The ***pectoral, rectus abdomins obliquus externus*** and ***latissimus dorsi*** are other muscles found on the trunk. In the thigh the ***sartorius*** muscle arises from the ilium and is inserted on the head of tibia. Its contraction pulls the hindleg forward ventrally. The ***triceps femoris*** pulls the whole hindleg forward. The ***gastrocnemius*** is a very important muscle in the hindleg of frog. It arises mostly from the femur and terminates in a strong tendon called ***tendo Achilis***, which

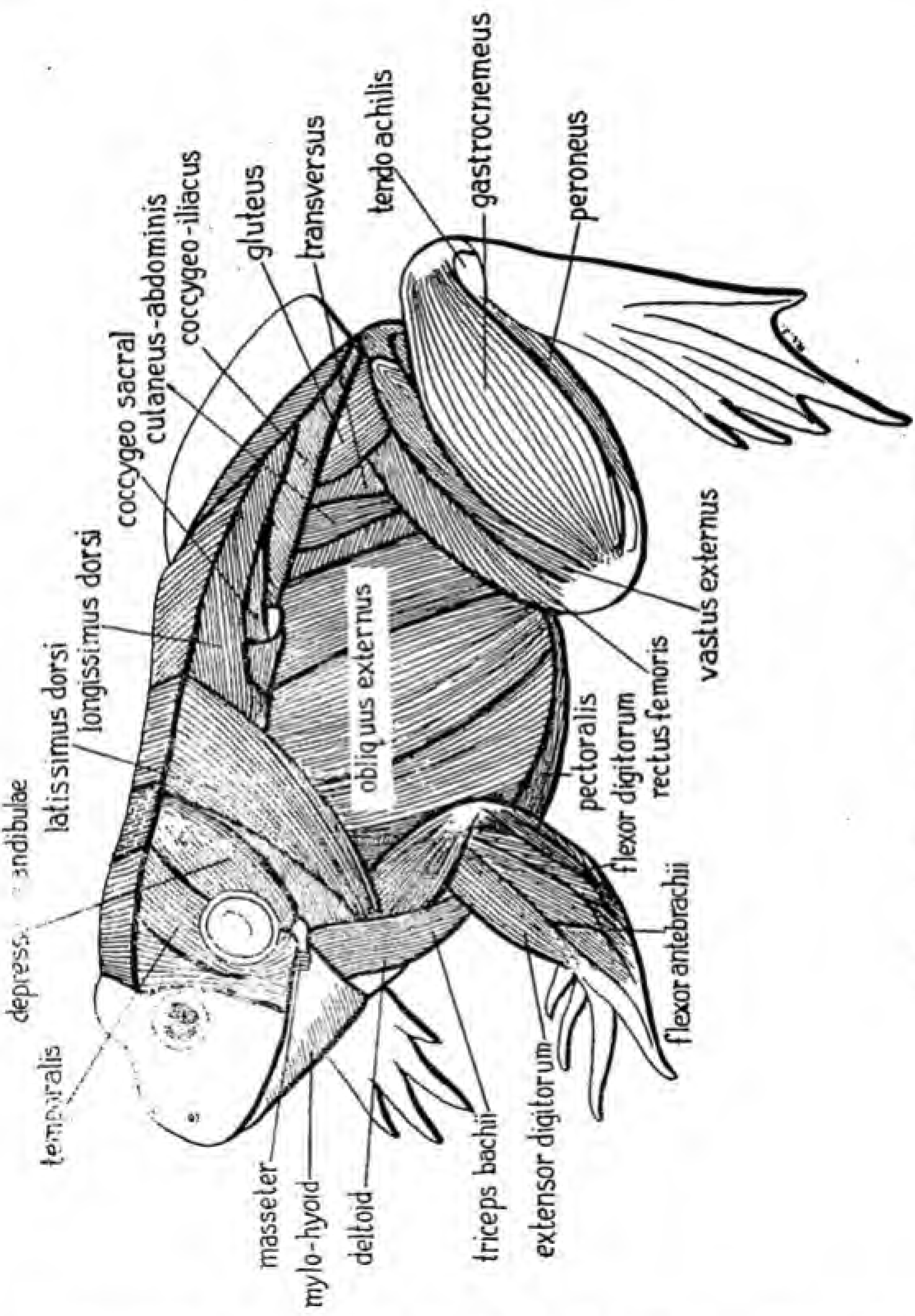


FIG. 91. Superficial muscles of the frog in lateral view.

spreads out on the sole of the foot. When this muscle contracts, the foot is extended and the ankle is flexed.

10. NERVOUS SYSTEM

Definition and function.—The nervous system is essentially a ***conducting mechanism,*** which has often been compared to a telephone system. The various organ systems of the frog which have been described so far do not operate entirely by themselves and independently of others. They all work not only together but also in a co-ordinated manner. This control and co-ordination is brought about by the activity of the nervous and endocrine systems. The endocrine system brings about chemical regulation and will be described in the next section. The nervous system receives stimuli of various kinds, transmits nerve impulses to the central office—the brain—for interpretation, decision, adjustment and relay to the proper destinations. The nervous system therefore serves two purposes : 1. it co-ordinates the activities of different parts of the body, 2. it enables the animal to perceive the external world and respond to external stimuli.

Units of the nervous system.—The unit structure of the nervous system is the nerve cell or ***neuron.*** Like all the other cells of the body a neuron consists of a nucleus and cytoplasm. From the cell body extends two kinds of cytoplasmic processes of the neuron : ***dendrons*** and ***axons.*** The dendrons, also called dendrites, are branched cytoplasmic processes of the nerve cell. There are usually several such processes to a neuron There is only one axon to a neuron Axons are often very long and usually not branched in the manner of dendrons. The dendrons and the axons are the conducting wires for the nerve impulses. The direction of conduction of these impulses in these processes is definite. The dendrons always conduct the impulses to the neuron, while the axons always convey the impulses from the neuron outward. The axon of a neuron may end in a gland or in a muscle. It may also lie in ***contact*** with the dendron of another neuron; this contact is called ***synapse.*** A synapse enables the impulses received by one neuron to be relayed on to another. A bundle of axons and dendrons or of both, bound together by insultating connective tissue sheath, is a ***nerve.*** A nerve is thus merely a bundle of insulated conducting tissue connected to the nerve cell. The axons and dendrons thus constitute ***nerve fibres.*** A nerve composed entirely of dendron fibres conveys the sensory impulses from different parts of the body to the central neuron; it is a ***sensory*** or an ***afferent*** nerve. A nerve made wholly of axon fibres conveys impulses to some outlying part of the body and is an ***efferent*** nerve. Most efferent nerves end in a muscle and the result of the impulse they carry is a muscular contraction and movement. They are therefore also called ***motor*** nerves.

The outer endings of the sensory nerves are the ***receptors,*** which receive the sensation of a stimulus. The nerve is the ***conductor*** of this sensation to the ***adjustor.*** The adjustor now sends out a response along the motor nerve to the ***effector,*** which may be a muscle or some such organ. Receptors are of various kinds : chemical receptors for smell and taste; mechanical receptors for touch and sound; light receptors for sight and so on.

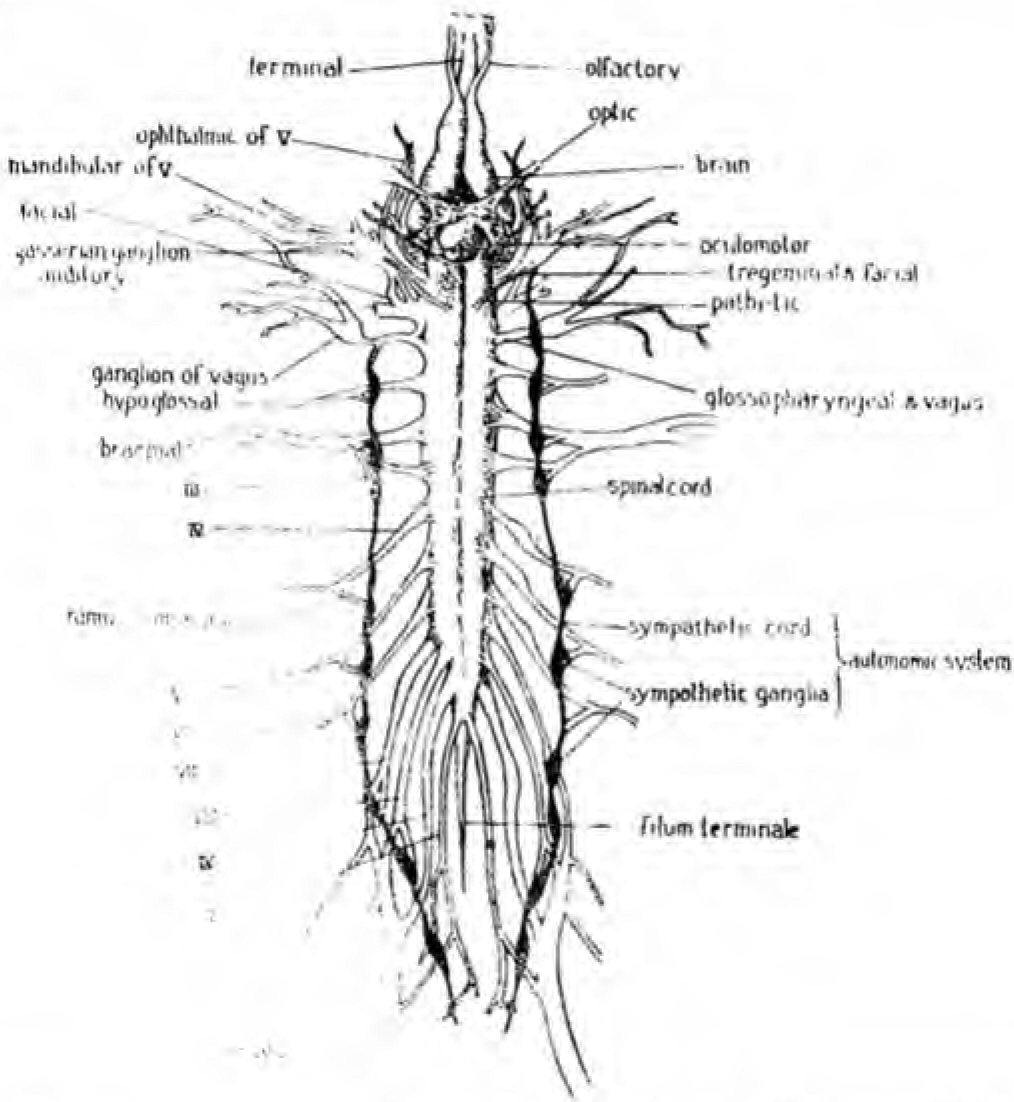


Fig. [illegible] Nervous system of the frog in ventral view. The autonomic system is shaded black.

Parts of the nervous system.—The parts of the nervous system of the frog are the ***central*** nervous system, the ***peripheral*** nervous system and the ***autonomic*** nervous system.

The central nervous system of the frog comprises the ***brain*** and the ***spinal cord.*** The peripheral nervous system includes

Лев Толстой
ВАС СКА 361

cranial nerves and ***spinal nerves*** which connect respectively the brain and the spinal cord with various organs; and autonomic nervous system controls the involuntary activities of the visceral organs.

Brain.—The brain is the great co-ordinating and adjusting centre of the body. It is composed of grey matter on the outer surface and white matter inside. The brain is not solid but encloses cavities called ***ventricles*** of the brain. It is protected by two membranes: an outer ***dura mater*** and inner ***pia mater.*** The dura mater closely adheres to the cranium. The pia mater is relatively deeply pigmented and adheres to the brain. It is richly supplied with blood capillaries. The interspace between these membranes is filled with the ***cerebrospinal fluid.*** The ventricles of the brain are also filled with same fluid.

The brain comprises 1. ***prosencephalon*** or the forebrain, 2. ***mesencephalon*** or the midbrain and 3. ***rhombencephalon*** or the hindbrain. The forebrain itself consists of a ***telencephalon*** and ***thalamencephalon*** or ***diencephalon.*** The telencephalon shows two distinct divisions: anterior ***rhinencephalon*** or the olfactory lobes and posterior ***cerebral hemispheres*** or the great brain. The olfactory lobes are the anterior-most part of the brain and are two elongated rounded bodies, directly continuous behind with the cerebral hemispheres but distinctly demarcated from them by a depression. They are the centres for the sense of smell. The cerebral hemispheres are concerned with voluntary motion, intelligence and memory. They are the seat of mind. In the frog however they are relatively small and their removal by a surgical operation is not fatal to the frog. The telencephalon is dorsally cleft by a median longitudinal fissure into a right and a left half.

DIVISIONS OF THE BRAIN

- Encephalon (Brain)
  - I. Prosencephalon (Anterior cerebral vesicle Primary fore-brain)
    - Telencephalon (End-brain)
      - Olfactory lobe (Rhinencephalon)
      - Cerebral hemisphere
      - Telencephalon medium
    - Diencephalon (Inter-brain)
      - Mamillary portion of hypothalamus
      - Thalamencephalon
  - II. Mesencephalon (Middle cerebral vesicle Primary midbrain)
    - Corpora bigemina (Optic lobe)
  - III. Rhombencephalon (Posterior cerebral vesicle Primary hind-brain)
    - Metencephalon (Cerebellum)
    - Myelencephalon (Medulla oblongata)

The thalamencephalon is a depressed region of the brain. It includes the ***optic thalami, infundibulum*** and ***pineal body.*** The lateral walls of the thalamencephalon are thickened into the ***opticthalami;*** the floor and roof remain comparatively thin. The cavity thus enclosed is called the ***third ventricle*** of the brain. The floor of the third ventricle is produced ventrally into a conical ***infundibulum.*** It is connected below and behind to a reddish ***hypophysis.*** The infundibulum and the hypophysis constitute together the ***pituitary body.*** The pituitary body has many important functions, which will be discussed in the section on endocrine organs. The roof of the thalamencephalon is produced into a finger-like ***pineal body.*** The pineal body occurs in all the Craniata and represents a lost median eye. It is located by the ***brow spot*** on the surface of the head. In front of the pineal body there is a richly vascular anterior ***choroid plexus,*** the blood capillaries of which bring the nourishment to and carry away the wastes from the brain.

The midbrain. The midbrain is the widest part of the brain. It comprises dorsally a pair of large ovoid swellings, the ***corpora bigenmia*** or the optic lobes. The floor of the midbrain is called ***crura cerebri.*** The optic lobes are connected to the eyes, which are concerned with the sense of sight.

The hindbrain.—The hindbrain is continuous with the midbrain. It includes 1. ***metencephalon*** or ***cerebellum*** and 2. ***myelencephalon*** or the ***medulla oblongata.*** The metencephalon or the "little brain" lies behind the optic lobes. It is quite small in the frog and forms the roof of the hindbrain. It is the centre for equilibrium and co-ordination of movements of parts of the body.

The myelencephalon is the hind-most part of the brain and it gradually merges into the spinal cord behind. It is wide in front and tapers behind. Its floor and sides are thick but dorsally there is a deep broad triangular depression, the cerebellum forming the base of the triangle. This depression is the ***fourth ventricle*** of the brain. It is roofed over by a thin highly vascular membrane, the ***posterior choroid plexus.*** The medulla oblongata receives stimuli from the viscera through the autonomic nervous system. It regulates the unconscious or automatic activities like heart-beat, movements of lungs, etc. It also controls the peristaltic movements of the alimentary canal and the action of the glands. If the rest of the brain of the frog is cut off by surgical operation, leaving only the medulla oblongata, the frog continues to live, breathe and swallow any food placed in

its mouth. If however the medulla oblongata is destroyed, death follows immediately.

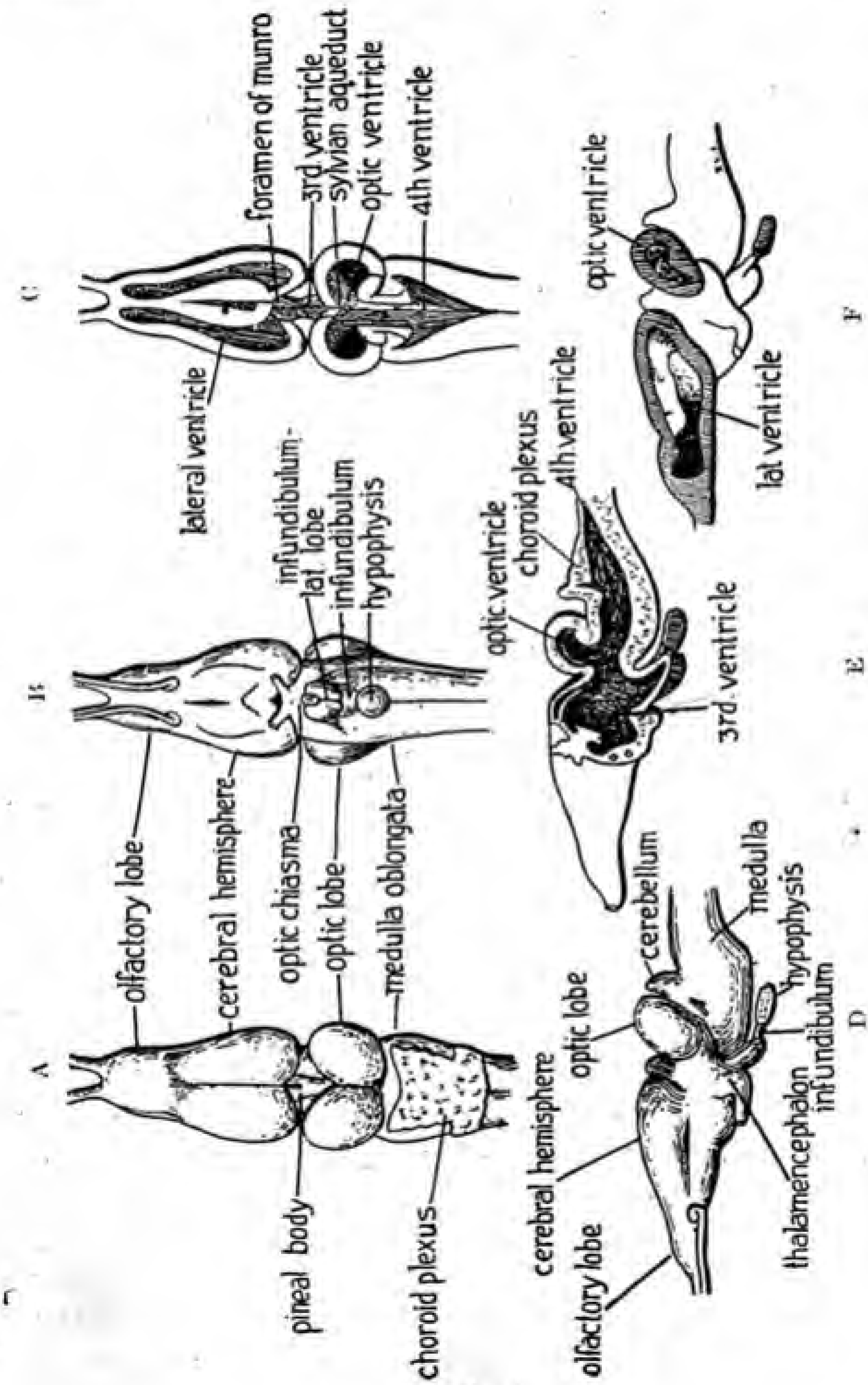


FIG. 55. The brain of frog. A. Dorsal view. B. Ventral view. C. Horizontal section. D. Lateral view. E. Median longitudinal vertical section. F. Longitudinal vertical section at the side.

Cavities of the brain.—There are four ventricles in the brain. The first ventricle is the cavity of the right cerebral hemisphere. The cavity of the left cerebral hemisphere is the second ventricle. The first and second ventricles are together often called the ***lateral ventricles.*** A T-shaped canal, the ***foramen of munro,*** connects the two lateral ventricles with the third ventricle, which is the cavity of the diencephalon. The third and the fourth ventricles are connected together by the ***sylvian aqueduct,*** which also joins the cavities of the optic lobes.

Spinal cord.—The medulla oblongata of the brain continues posteriorly as the ***spinal cord.*** The spinal cord passes out through the ***foramen magnum*** between the exoccipital bones. It runs through the neural canals

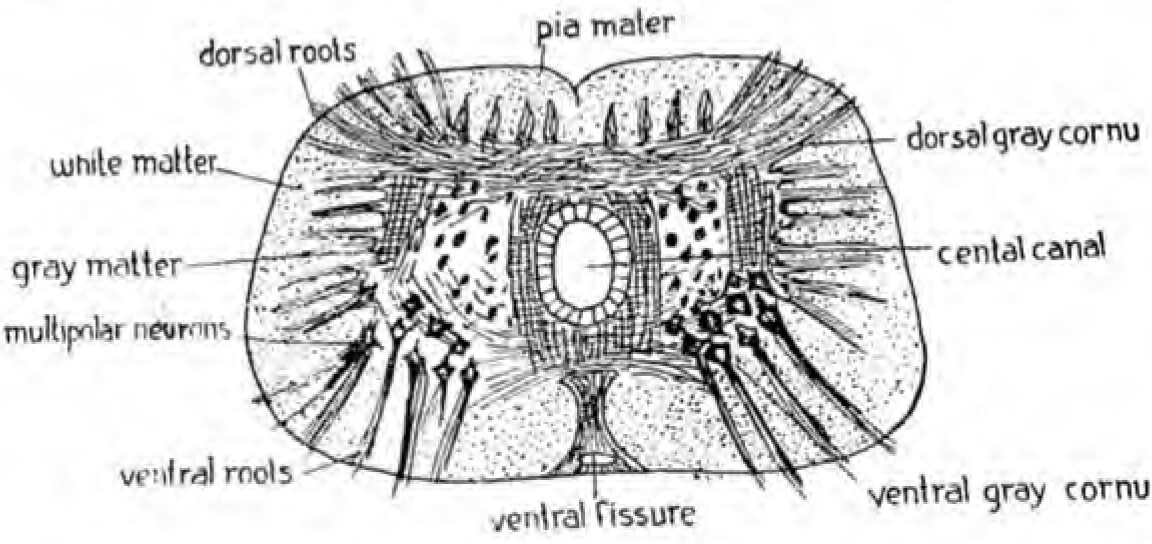


Fig. [illegible]. Frog. Spinal cord in transverse section. (Read Central Canal for [illegible])

of the vertebrae into the urostyle. The brain and the spinal cord are directly continuous; the brain is really the enlargement of the anterior end of the spinal cord. It is likewise covered by dura and pia mater. Like the brain, the spinal cord is also composed of grey and white matter but in the spinal cord the white matter is on the outer surface and the grey matter deeper within. The spinal cord encloses a central canal running from the posterior end to the anterior and communicating with the fourth ventricle of the brain. The spinal cord is not perfectly circular in cross section but is somewhat flattened dorso-ventrally. It is not uniform in thickness but presents an anterior enlargement in the second and third vertebrae and a posterior enlargement in fifth and sixth vertebrae. It is reduced beyond the seventh vertebra to a fine slender thread, the ***filum terminale*** in the urostyle.

Dorsally and ventrally the spinal cord is deeply fissured by the median longitudinal fissures. The dorsal fissure is well marked in the middle. The ventral fissure is well marked nearly throughout but both the fissures disappear in the hinder part.

The spinal cord is the great "highway" for most nerve impulses. It conducts impulses to and from the brain. It also acts as a "reflex centre".

Peripheral nervous system.—The Peripheral nervous system connects various parts of the body with the spinal cord and the brain. It comprises eleven pairs of cranial nerves and ten pairs of spinal nerves. The cranial nerves communicate with the brain directly. The spinal nerves communicate with the spinal cord.

Cranial nerves.—These arise from the brain and all except the last go to the sense organs. The last cranial nerve supplies nerve branches to the viscera. For a long time it was believed that there are only ten pairs of cranial nerves in the Amphibians. These were numbered one to ten with roman numerals and were also given special names. Recently however an additional nerve, anterior to the first pair, was discovered in many fishes and all Amphibians. To avoid confusion, this nerve is numbered zero and is called the ***terminal nerve,*** thus retaining the same number and names for the remaining as of old. The terminal nerve goes to the nasal chamber and is believed to be a sensory nerve. The first pair, the ***olfactory*** nerve, arises from the anterior end of the olfactory lobes of the brain and runs to the nasal chambers The second pair is the ***optic nerve.*** The optic nerve arises beneath the optic lobes. Each optic nerve runs forward and inward to meet in the ***optic chiasma*** in front of the infundibulum. Here most of the fibres of the optic nerve cross over to the opposite side, so that the eye of the right side is connected with the left optic lobe and the left eye is connected with the right optic lobe. They enter the inside of the eye and spread out into a network called ***retina*** or the light sensitive inner layer of the eye. They are sensory nerves that convey the sensation of light to the brain. The third pair is the ***oculomotor*** nerve, which arises from the midbrain and supplies the muscles which rotate the eyes. The fourth, called ***pathetic*** or ***trochlear*** nerve, is also a motor nerve going to the muscles of the eye. The fifth pair or the ***trigeminal*** nerve is the largest of the cranial nerves of the frog. It arises anteriorly from the medulla oblongata, passes forward and outward and swells into a prominent ***gasserian ganglion*** before coming out of the cranium. It then divides into two branches : the ***opthalmic*** nerve and ***mandibulo-maxillary*** nerve. The former goes between the cranium and eye ball and supplies branches to the nose and skin

in the anterior part of the head. The latter nerve divides into a ***maxillary*** branch going to the upper jaw and a ***mandibular*** branch going to the lower

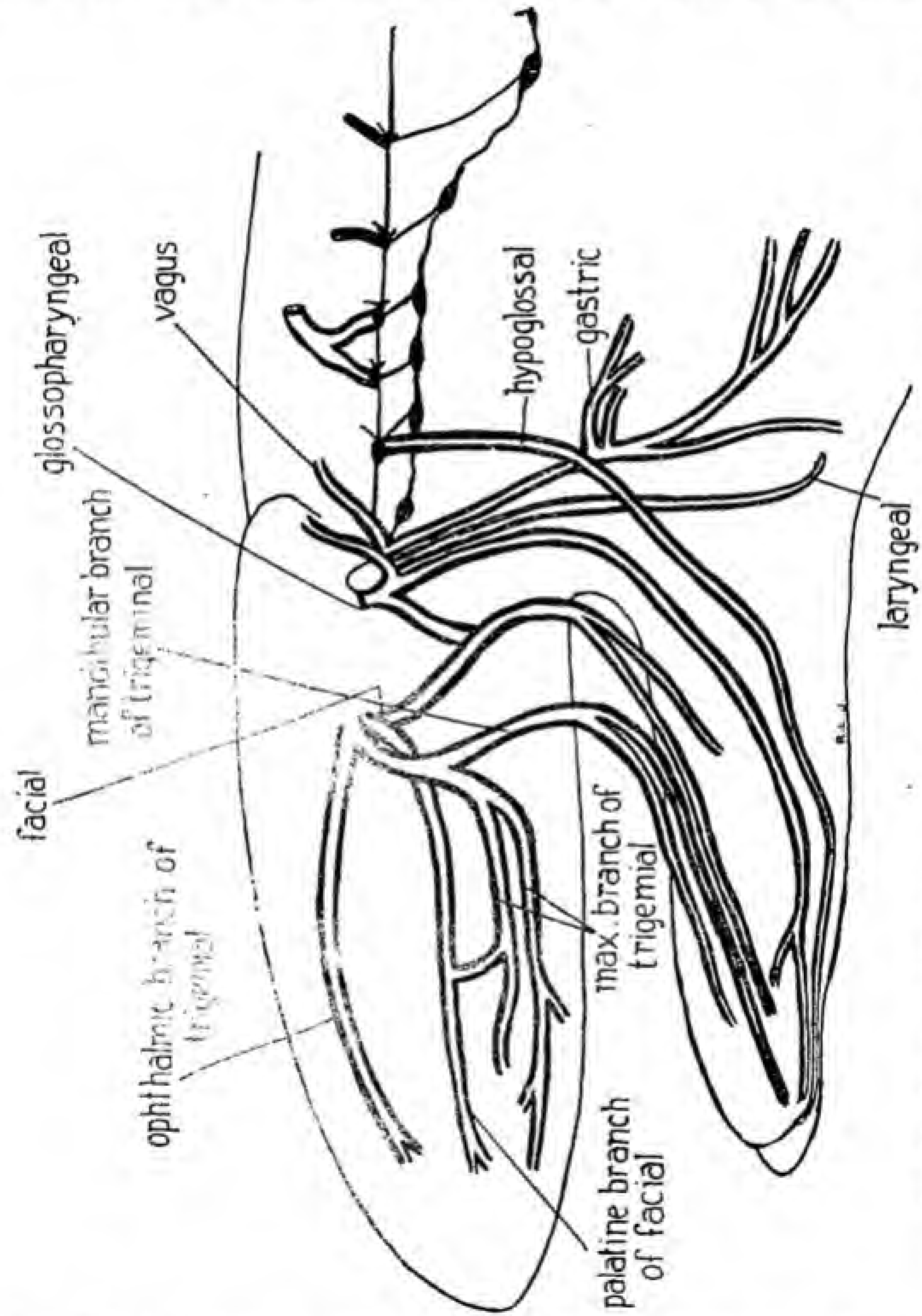


FIG. 95. Diagram of the trigeminal and vagus nerves of the frog and their connections to other cranial nerves and autonomic system (in solid black) in lateral view.

jaw. The trigeminal is both a sensory and motor nerve and its branches go to the jaws, skin, teeth, tongue and the muscles that move the jaws. The

sixth or the ***abducens*** is a motor nerve going to the muscles of the eye ball. The seventh, ***facial,*** is a sensory and motor nerve and arises from the medulla oblongata behind the trigeminal. It runs forward to unite with the gasserian ganglion and then runs close to the mandibular branch of the trigeminal and divides into a ***palatine*** nerve to the roof of the buccal cavity and a ***hyomandibular*** nerve. The ***auditory*** nerve is the eighth pair. It is a sensory nerve arising from the medulla oblongata behind the seventh and going to the otic capsule and suppling the organ of hearing. It conveys the sensation of sound. The ninth, called the ***glossopharyngeal,*** arises behind the auditory nerve and supplies sensory and motor branches to the tongue and pharynx. The tenth is called ***vagus*** or ***pneumogastric*** nerve. It sends complicated branches to the pharynx, larynx, oesophagus, heart, lungs, etc.

Spinal nerves — Ten pairs of nerves arise from the spinal cord and go to the trunk and limbs The first spinal nerve is the ***hypoglossal,*** which passes out of the vertebral column between the atlas and the second vertebra, and runs forward to the root of the tongue. The second or the ***brachial*** is a stout nerve coming out of the vertebral column between the second and the third vertebra. It passes outward to the forelegs after giving off branches to the pectoral girdle. The third spinal nerve joins the brachial. The fourth, fifth and sixth pairs of spinal nerves supply the muscles of the trunk. The seventh, eighth and ninth run back and unite together into a stout trunk, with which the tenth also joins and thus from the ***sciatic*** nerve. It is the stoutest nerve in the body of the frog and runs into the hind legs, giving off branches to the leg muscles.

Each of the spinal nerves arises by a dorsal sensory and a ventral motor root. The dorsal root has a ganglionic enlargement but the ventral root is without one. The two roots unite to form a single nerve before coming out of the vertebral column.

Brachial and sciatic plexuses.—A plexus is a network of branches from several nerves. The brachial plexus is formed by the branches of the first, second and third spinal nerves. The sciatic plexus is formed by branches from the seventh, eight and ninth spinal nerves.

The autonomic nervous system.—The autonomic nervous system consists of chains of ganglia on either side of the vertebral column, prevertebral plexuses and peripheral ganglia in various parts of the body. It regulates the working of the heart and other visceral organs, the movements of the involuntary muscles, the muscles of the blood vessels, etc. Most organs receive a double set of nerves of this system :

one set accelerates and the other inhibits or retards the activities of the organ.

The chain of ganglia are connected by longitudinal cords and each ganglion is further connected with a spinal nerve by a ***ramus communicans.*** The first pair of ganglia lies on the hypoglossal nerve. The second ganglion is the largest of the series. It is placed on the brachial nerve It is connected to the spinal nerve by fine fibers The third is fused with the second The succeeding ganglia lie on either side of the vertebral column and at about the level of the sixth vertebra follow the course of the dorsal aorta. From this region the rami communicantes are long.

The ganglia send out numerous branches which divide and subdivide and form an interlacing network of plexus. A ***cardiac plexus*** is formed by the nerves from the first ganglion and lies on the auricles. The ***solar plexus*** is formed by the branches from the third, fourth and fifth and is located dorsally on the stomach. Anteriorly the ganglia communicate by a branch with the vagus nerve The autonomic nervous system is thus not an isolated system but is imtimately connected both with the spinal cord and brain.

Nervous system in action.—For the action of the nervous system at least two neurons are involved. One neuron is called a ***sensory neuron,*** because its dendron brings in a sensory impulse of some kind, for example, a pinprick on the skin of the finger. The axon of this neuron is in synapse with one of the dendrons of another neuron, which is called a ***motor neuron.*** The impulse now passes from the receptor through the sensory neuron, out of it by the axon and to the motor neuron by way of the synapse. It does not end here. It continues through the motor neuron and into the axon of this neuron. This axon may end in a muscle of the finger. When this impulse now arrives in the effector, *i.e.* the muscle, the latter contracts and the finger is withdrawn. The sensory impulse has thus been reflected so to speak by the neurons down the motor nerve, resulting in an automatic muscle contraction. Such an immediate involuntary response to a sensory stimulus is called ***reflex action.*** The path travelled by the impulse is called a ***reflex arc.*** The synaptic connection between the sensory and motor neurons lies in the spinal cord. Nerve impulses always pass across a synpase only in one direction, thus avoiding confusion. Nerve impulses travel in the frog at a speed of 27 metres per second. The cell bodies of the sensory neurons are also located in the brain and spinal cord. The sensory neurons are connected by intermediate neurons with motor neurons, so that there is complete

co-ordination. Reflex actions therefore arise in the spinal cord or in the brain. Reflex movements are not so simple as the one described above

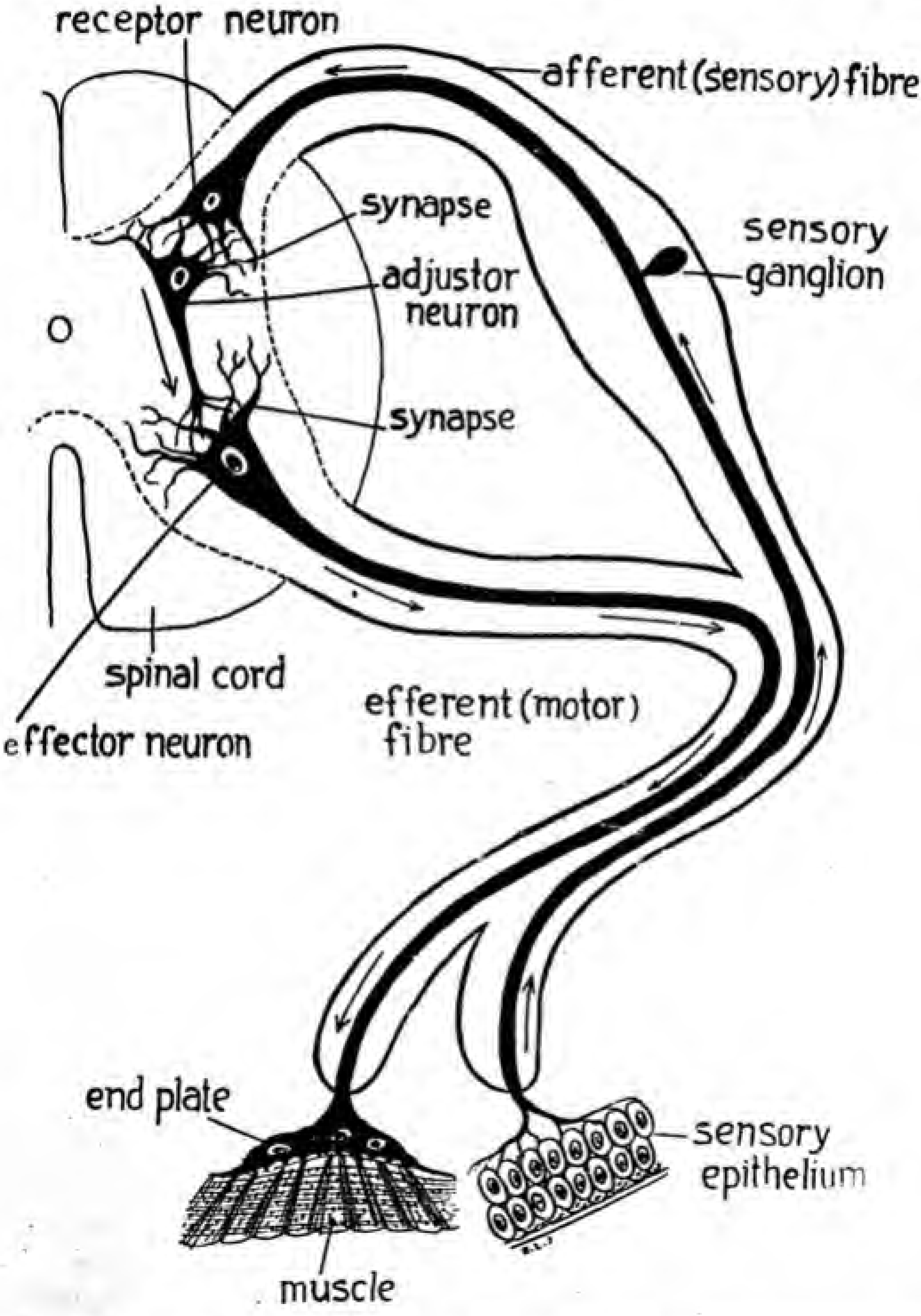


FIG. 96. Simplified diagram of the spinal cord of frog, showing the relation of the neurons involved in a simple reflex action. A simple reflex arc.

by way of an example, but may involve movements of the entire body and secretions of glands. A pinprick if severe, for example, causes only the movement of the finger and perhaps also the flow of tear but a sudden and loud explosion makes the entire body start. Common examples of reflex actions are numerous and are all automatic, that is they are not concerned with the will power.

There are two types of reflex actions : the ***unconditioned reflex*** and the ***conditioned reflex***. The withdrawing of a finger at a pinprick, the sudden fright at the sight of a snake, the winking of the eye at sudden approach of an insect, etc., are some of the common examples of the unconditioned reflexes. Most of the actions of the frog are of this type. A frog automatically snaps with its tongue any moving object, hops away at sight of danger and does many other things purely by reflex impulses. The will power of the frog is not at all involved in most of its activities. People often call such actions as ***instinct*** in the case of animals and as ***habit*** in the case of man.

A conditioned reflex is an action which has been so often repeated that it becomes a habit. Pavlov, a Russian physiologist, showed that if every time food is offered to a dog and a bell is rung, after some time the flow of saliva (watering of the mouth!) will take place even if the bell is rung but no food is offered. The watering of the mouth has been repeated so many times for the bell-ringing, that it has become a habit with the dog, so that sound of the bell alone automatically makes the mouth water, though there is no food in sight. This is conditioned reflex. A conditioned reflex leads to learning by trial and error. ***Learning*** is modification of behaviour by previous experience. A frog can learn after many failures and trials, sometimes a hundred attempts alone will make it change its action.

Receptors ; organs of special sense.—Sense organs are specialized in their susceptibility to a particular kind of stimuli, for example, the tactile, pain, warmth, cold, chemical (taste and smell), sound, light and gravitation (equilibrium).

The tactile organs of the frog are the nerve plexuses of the skin, ***touch spots*** of *Merkel*, ***touch corpuscles*** of the tendons, etc. The organs of taste are not confined to the tongue alone but also occur on the roof of the buccal cavity near the vomerine teeth. These comprise the ***filiform papillae*** and ***fungiform papillae***. The former are conical structures and the latter are large and broader at the tip than at base. They are supplied with blood capillaries and nerve branches. The olfactory sense organ is the nasal cavity, which consists of three chambers lined by sensory

mucus. A frog uses the power of smelling not merely for judging the suitability of food but also perhaps in avoiding enemies.

The eye is the organ of sight. The frog's eyes are very much like those of man in their structure. They lie in the large orbits and are prominently situated on the head Each eye is so placed that it covers different fields of vision, so that a frog does not see things exactly as we see them. Frogs do not thus have ***binocular*** vision. They cannot therefore judge distances of the objects they see The eye of the frog is however well adapted for detecting movements.

Each eye is rotated by six muscles that are attached on its outer surface : 1. rectus inferior, 2. rectus externus, 3. rectus internus, 4. rectus superior, 5. obliquus inferior and 6. obliquus superior.

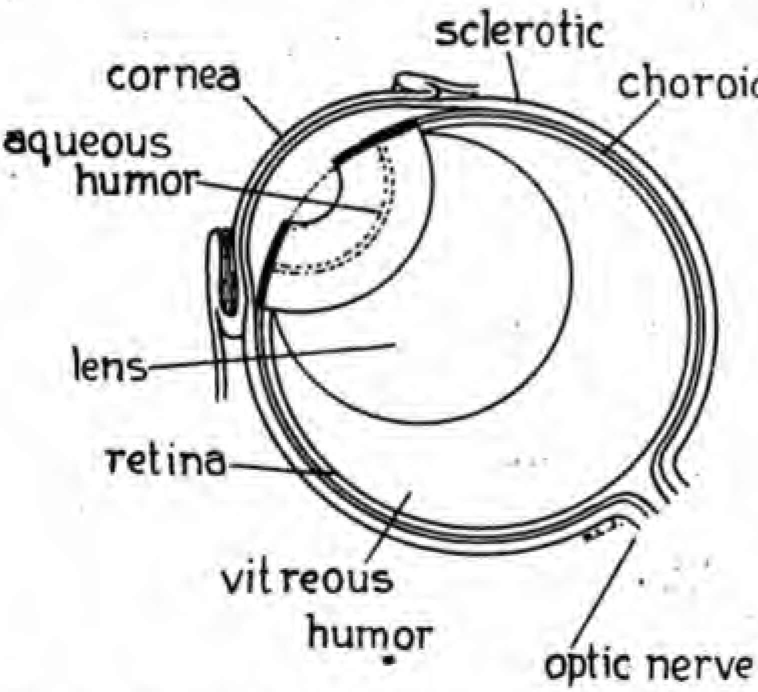


FIG. 97. Diagram of vertical section through the eye of frog.

The eye is analogous to the photographic camera. It is essentially a light-proof box with a biconvex lens to form an image of the object on a light-sensitive screen. The eyeball is composed of three coats. The outer is the ***sclerotic*** coat composed of tough cartilage and dense white connective tissue. In front it is continuous with a transparent ***cornea,*** which permits light rays to enter the lens behind. Beneath the sclerotic coat lies the ***choroid*** coat, which is rich in blood capillaries and contains a black opaque pigment so as to exclude all light

except that passing through the cornea and thus make the cavity of the eyeball a light-proof chamber. The innermost coat is ***retina,*** which is the light-sensitive surface of the eye. The retina is connected to the optic lobes of the brain by the optic nerve. It is composed of several minute layers, of which an outer pigmented and an inner thicker one are important. In the latter are the ***rods*** and ***cones.*** The rods form colourless sensations in dim light and the cones are sensitive to bright light and colours. Behind the cornea, within the eyeball cavity, there is a pigmented disc, the ***iris*** with a central opening, the ***pupil.*** The iris is provided with circular and radial muscle fibres by means of which the pupil can be dilated or contracted to let in more or less light as required. Behind the pupil is the almost spherical ***lens,*** which focusses the image of objects on the retina. The lens of the frog's eye cannot change its shape or its distance from the retina as in the case of man, so that the frog's eye is a ' fixed-focus box Brownie camera". The space in front of the lens is filled with a watery liquid called the ***aqueous humour*** and that behind it with a glass-like ***vitreous humour.***

The frog's auditory organs comprise the ***tympanum,*** the ***middle*** ear and the ***internal*** ear or the ***membranous labyrinth.*** The tympanic membrane externally covers the tympanic cavity. This cavity is a funnel shaped passage bounded above and below by the squamosal bone. The cavity communicates with the buccal cavity by the wide short ***eustachian tube,*** so as to equalize the pressure of air on both sides of the ear drum and thus prevent bursting of the drum on sudden explosions. In the tympanic cavity lies a rod of bone, the ***columella auris,*** the outer end of which is attached to inner surface of the tympanum and the inner end to the inner ear.

The internal ear consists of a membranous structure floating in the ***perilymph*** fluid enclosed within a cartilagenous cavity of the otic capsule. The membranous sac is filled with ***endolymph.*** It comprises an upper larger ***utriculus*** and a lower smaller ***sacculus.*** The sacculus has a tube, the ***ductus endolymphaticus*** opening into it. The utriculus gives off three ***semi.circular canals*** : 1. the anterior median vertical, 2. posterior transverse vertical at right angle to each other and 3. the median horizontal. Thus the three semicircular canals are at right angles to each other in three different planes. All the canals open into the utriculus at both ends but each forms an ampulla only at one end. The otic capsule is closed off by a membranous inner drum, which is connected by the columella to the tympanum. Vibrations of sound in the air set up corresponding vibrations

in the tympanum. These vibrations are conveyed through the columella

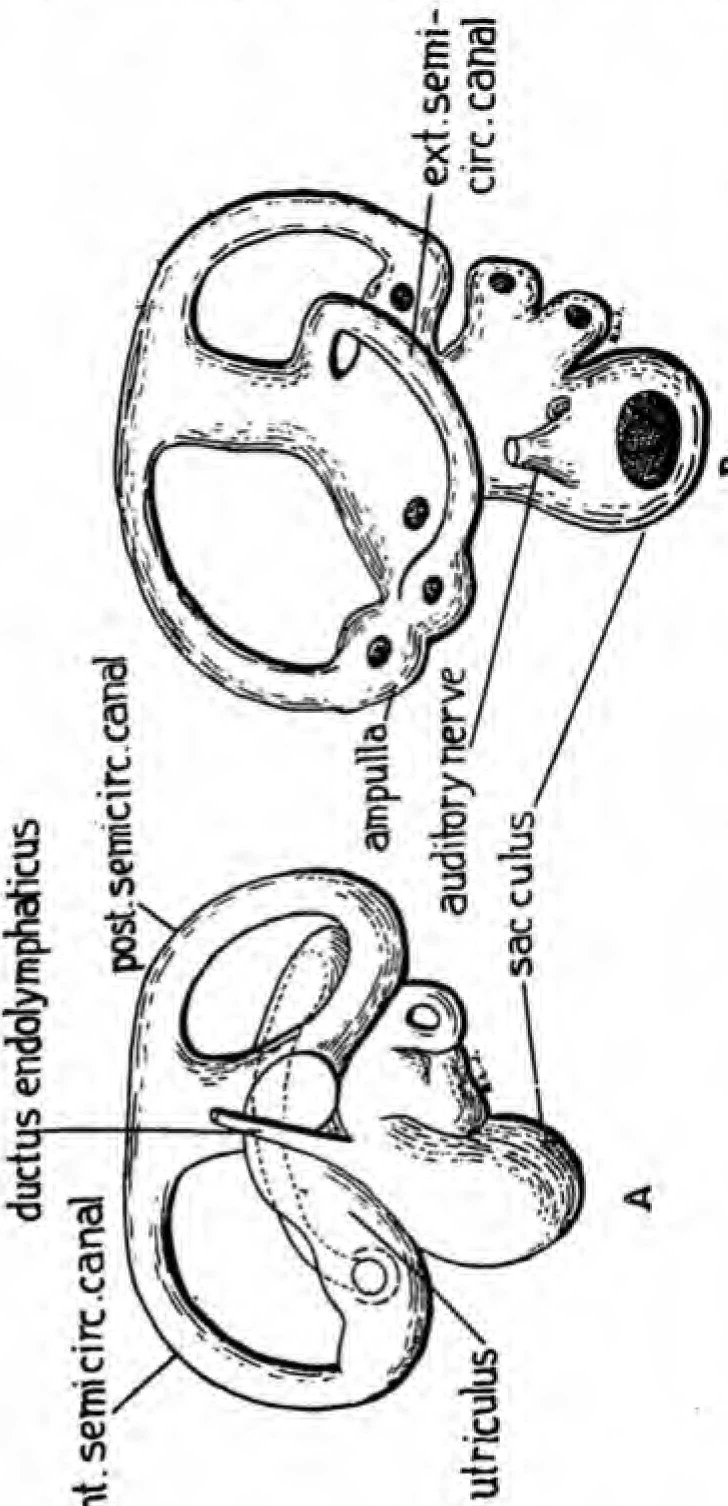


FIG. 98. The membranous labyrinth of the internal ear of frog. A. Inner view. B. Outer view.

to the inner membrane. The vibrations of this membrane become

transferred to the endolymph as changes of liquid pressure. The auditory nerve sends out branches into the endolymph within the utriculus, ampulla, etc. Their cavity is thus lined by sensory hair-like processes, to which often calcareous crystals or concretions of calcium carbonate become attached. These hairs convey through the nerve-endings the sensation of changes of pressure in the endolymph to the myelencephalon, from which the auditory nerves come out. The brain interprets these sensory impulses as sound. It is only the sacculus which serves to receive sound vibrations. The semicircular canals have another important function to perform. Being arranged roughly at right angles to each other in three different planes. they have the function of perceiving changes in the direction of gravitation brought about by the moving of the frog. They thus serve in maintaining the equilibrium, in other words, they are ***static organs.***

II. ENDOCRINE SYSTEM

The endocrine system of organs are agents of chemical co-ordination. Endocrine glands have no special ducts to convey their secretions, the ***hormones***, to a particular organ. Their secretions are discharged into the blood stream and thence into the general circulation of the body and thus reach all parts. They are therefore called ***ductless*** glands or also ***internal secretion glands*** in contradistinction to the ordinary ones, which pour their secretions outside by ducts.

The endocrine organs share with the nervous system the function of co-ordination. They bring about this by their hormones. Hormones, though released into the general circulation, have specific action on certain organs only. They affect the functions of the various parts of the body and also of other ductless glands. The endocrine organs are therefore a sort of "interlocking command-directorate general" of the body. They are responsible for the metamorphosis of the tadpole into the frog, for the control of many visceral organs, behaviour of the animal, etc.

The following endocrine glands are found in the frog: 1. pituitary, 2. thyroid, 3. thymus, 4. adrenal, 5. pancreas and 6. gonads.

The pituitary.—The pituitary body is a blunt triangular outgrowth of the floor of the brain. It comprises the infundibulum and the hypophysis. The pituitary regulates the natural colour of the frog and also enables it to change its colour to suit background. It regulates the intake of water by the skin. It brings about the metamorphosis of the tadpole into the frog. It produces several hormones. In man for example excessive secretion of the pituitary hormones causes ***gigantism*** and

such men grow to 7 or 8 feet high. Under production of the hormones gives rise to ***obesity*** and ***dwarfness***. It leads to arrested sexual development. A pituitary hormone also controls the secretion of milk in females of Mammals. The growth and activity of the thyreoid and adrenal glands are stimulated by pituitary hormonens.

The thyreoid.—The thyreoid gland is situated behind the hyoid cartilage. It produces a hormone called ***thyroxin***. Thyroxin contains nearly 65% iodine. It regulates general metabolism. Removal of the thyreoid prevents metamorphosis of the tadpole. Thyreoid secretion also stimulates the development of the skeleton. In man the gland deficiency leads to ***cretinism*** or ***idiocy***. Cretins are dwarfs without proper sexual and mental development. They are often deaf-mutes and always idiots.

The thymus.—The thymus is situated on each side of the angle of the jaw below the mandibuler depressor muscle and behind the tympanic membrane. The thymus secretion stimulates the growth of the young tadpole of the frog and often causes them to grow to unusually enormous sizes before metamorphosis.

The adrenals.—These are narrow yellow glands located on the ventral surface of the kidneys and are also called ***suprarenal glands***. They produce a hormone called ***adrenalin***, which regulates blood pressure, mucular tone, etc. If these glands are removed by a surgical operation, the frog will die.

The pancreas.—The pancreas not only produces the pancreatic juice already referred to but also a special hormone called ***insulin***. Insulin is secreted by special groups of cells called the ***islets of Langerhans***. The presence of insulin is essential for the proper storage of glycogen in the liver. In man the absence of insulin causes diabetes.

The gonads.—The testes and ovaries produce certain hormones responsible for the development of secondary sexual characters, e. g., the vocal sacs and finger pads of male frog.

12. HISTOLOGY OF THE FROG

The Cell

Cell, the structural unit.—The ultimate structural unit of the body of the frog, as of all animals and plants, is the ***cell***. Cells were first discovered by ROBERT HOOKE in 1665 when he examined a piece of cork under the microscope. In 1839 a German biologist THEODOR SCHWANN showed that all parts of all animals and plants are composed of cells.

This generalization is called the ***cell theory***. According to this theory the cell is the fundamental structural and physiological unit of living organisms. Some animals are single cells, others comprise many cells. In the multicellular animals the life of the animal as a whole is the combined life of its individual cells. The cells are integrated for proper functioning. All multicellular animals begin their life as a single cell, which grows, repeatedly divides and thus gives rise to the manifold kinds of cells that compose the complicated organs of the body of the animal. The cell was defined by a Garman cytologist SCHULZE as a *corpuscle of protoplasm with a nucleus.* It is a mass of nucleated protoplasm enclosed in a membrane. Most cells are minute but some like the nerve cell (neuron) are often several feet in length. The largest cells are the yolks of large birds like the ostrich.

Animal cell.—A typical animal cell is bounded by a delicate elastic cell membrane. Beneath this membrane is a ***plasma membrane.*** The plasma membrane encloses viscous ***cytoplasm*** or cell protoplasm. Near the nucleus is a ***centrosome,*** in which occur some ***centrioles.*** There are often ***cytoplasmic inclusions*** like ***Golgi bodies, mitochondria, vacuoles,*** etc. The golgi bodies are believed to be concerned with the secretory activity of the cell. Mitochondria are granular, rod-like or thread-like bodies. Vacuoles are filled with liquids or gases. The nucleus is usually globose or oval and central in the cell. It is bounded by a ***nuclear membrane.*** There is a ***nuclelous*** in the centre of the nucleus. The nucleus is composed of ***nucleoplasm.*** Delicate threads of ***linin*** form a net-like structure in the nucleoplasm. ***Chromatin*** granules are scattered along the linin meshwork. The chromatin granules are merely the thickened parts of continuous linin thread. The nucleus is the most important part of the cell; there cannot be a cell without a nucleus. Protoplasm cannot exist in the absence of nucleus and nucleus also cannot have existence without cytoplasm.

Cells exhibit the metabolic activities of locomotion, nutrition, growth and respiration. They reproduce by dividing into two, each part growing into a mature cell. ***Cell division*** results in increase in the number of cells. There is thus a multiplication of cells. This leads to the growth of the animal as a whole. Cell multiplication also results in body repair. Dying cells are continually replaced by new cells. Most cells that compose the body have a definite life. Cells die daily and daily new cells are born. There is death and birth continually going on in the body of an animal. As long as the birth of the cells counterbalances their death, the animal as a whole lives.

Cell division.—The usual method of cell division is called ***mitosis*** or ***karyokinesis*** or indirect division. The division of the cell is preceded by a complicated series of changes in the nucleus and by division of the nucleus. Rarely, especially in the case of cancer, the nucleus divides directly and does not undergo a preliminary rearrangement of its substance. This type of cell division is known as ***amitosis*** or ***direct division***.

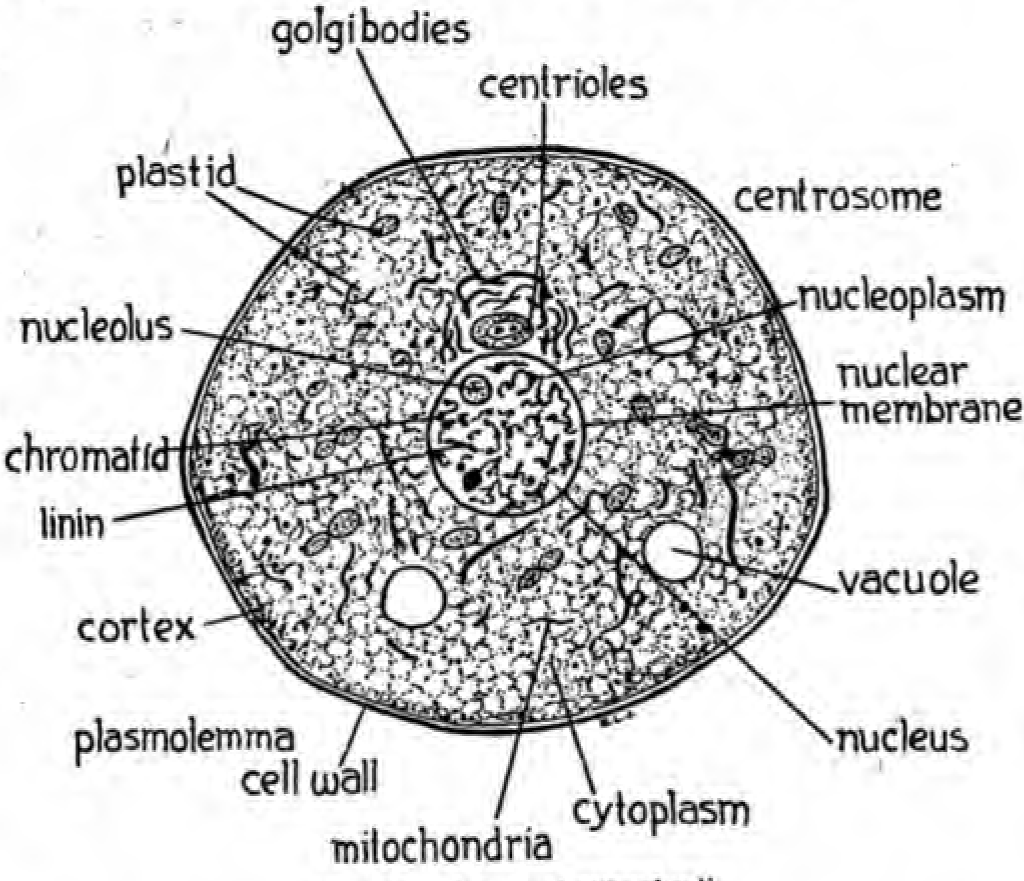


FIG. 99. A typical animal cell.

Mitosis.—Four more or less distinct but unbroken stages are usually recognized in mitosis, *viz.* 1. ***prophase***, 2. ***metaphase***, 3. ***anaphase*** and 4. ***telophase***.

Prophase.—The centrosome lies outside but close to the nucleus. It is surrounded by a mass of cytoplasm known as ***centrosphere***. The first indication of cell division appears in the centrosomes, of which there are generally two in the cell. If there is only one, it splits into two. The resulting halves migrate round to opposite poles of the nucleus. During their migration each half of the centrosome becomes surrounded by radiating fibrillae in the cytoplasm forming the so-called ***aster***. ***Spindle fibres*** are continuations of the asters separating the centrosomes.

Meanwhile the nucleus begins to undergo changes. The nucleus contains a network of fibrils of linin in which the chromatin is scattered. This network breaks up and becomes convoluted into ***spireme.*** The spireme quickly breaks up into a definite number of rod-shaped, curved or ovoid bits, the ***chromosomes***. The total number of chromosomes

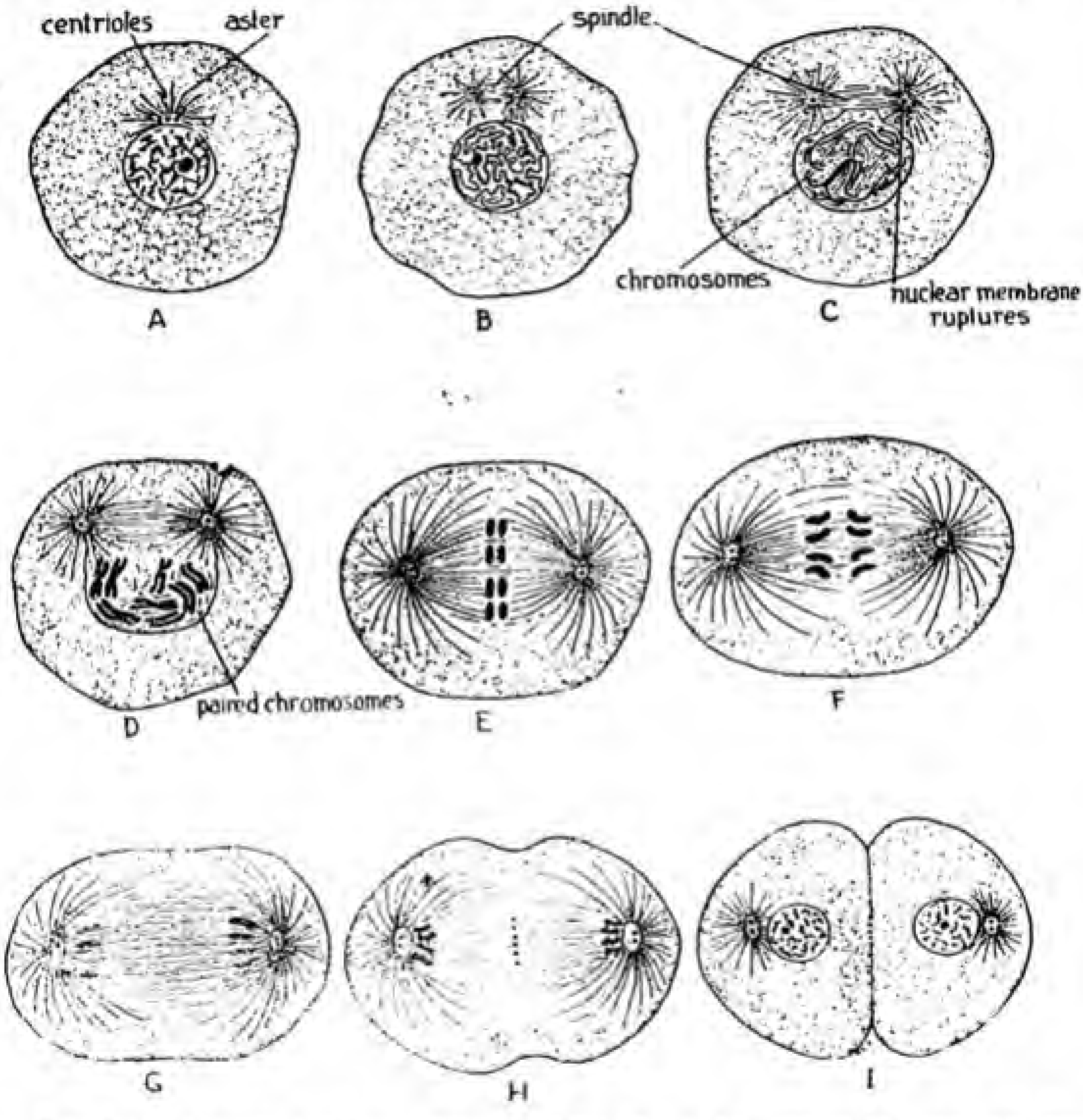


FIG. 169. Diagram of mitosis. A. Cell with the so-called resting nucleus containing chromatic reticulum and nucleolus before the beginning of division. The centrosome with the centrioles lies close to the nucleus. The nuclear division is heralded by the separation of the centrioles and appearance of the aster. B. The centrioles are separating and becoming surrounded by the astral rays. The chromatin forms the spireme threads. C-D. Polar spindles formed between the spiremes that have broken up into chromosomes. E. Chromosome division. F. Chromosomes diverge. G. The chromosomes collect at the spindle poles. H. Commencement of division of the cell body. I. Two daughter cells with reconstituted nuclei. A-D. Prophase. E. Metaphase. F-G. Anaphase. H-I. Telophase.

present at the end of the prophase is called ***diploid number*** which is constant for a particular species of animal. Different animals have

chromosome numbers. Man for example has 48, horse 60, dog 52, American bull frog (*Rana catesbeiana*) 26 and so on. While the chromosomes are appearing, the nuclear membrane disappears. The chromosomes now become attached to the spindle fibres. In the course of these changes the chromosomes have also split into two lengthwise.

Metaphase.—The chromosomes now arrange themselves in two groups equatorially across the cell and somewhat midway between the centrosomes. Equal numbers of identical chromosomes thus become segregated. They now migrate away from each other, each group travelling in opposite directions along the spindle threads.

Anaphase.—The repelling groups of chromosomes now reach the poles of spindles, where they crowd round.

Telophase.—The cytoplasm gets constricted in the plane of the equator. The chromosomes reconstitute themselves to form the original net-like pattern. A nuclear membrane appears around them. At the same time the equatorial constriction deepens until there are two complete daughter cells.

SYNOPSIS OF MITOSIS

I. Prophase

1. Chromatin-linin meshwork changes into chromosomes.
2. Centrioles migrate to the poles of the nucleus.
3. Astral rays develop round each centriole.
4. Spindle-fibres appear.

II. Metaphase

The longitudinally split chromosomes are located in the equator.

III. Anaphase

The two sets of identical chromosomes move to the polar asters.

IV. Telophase

The two sets of chromosomes reconstitute themselves into nuclei. Equatorial constriction of cytoplasm deepens and two daughter cells result.

TISSUES

In a multicellular animal like the frog the cells that compose the complex organs do not all perform the same function. There is division of labour. The cells have "castes" and different cells perform different functions. Some look after digestion, others transporation, still others conduction and so on. They have also different structures that fit them for their special kind of work. A group of cells similar in structure and function is a ***tissue***. The following tissues occur in the frog: 1. ***epithelial***, 2. ***sustentative***, 3. ***muscular*** and 4. ***nervous***.

Epithelial tissue.—The epithelial tissue (Fig. 101) is the oldest tissue in the body of an animal. All multicellular animals at one stage in their embryonic development consist entirely of epithelium. The cells of the epithelial tissue are compactly placed with but a small amount of intercellular

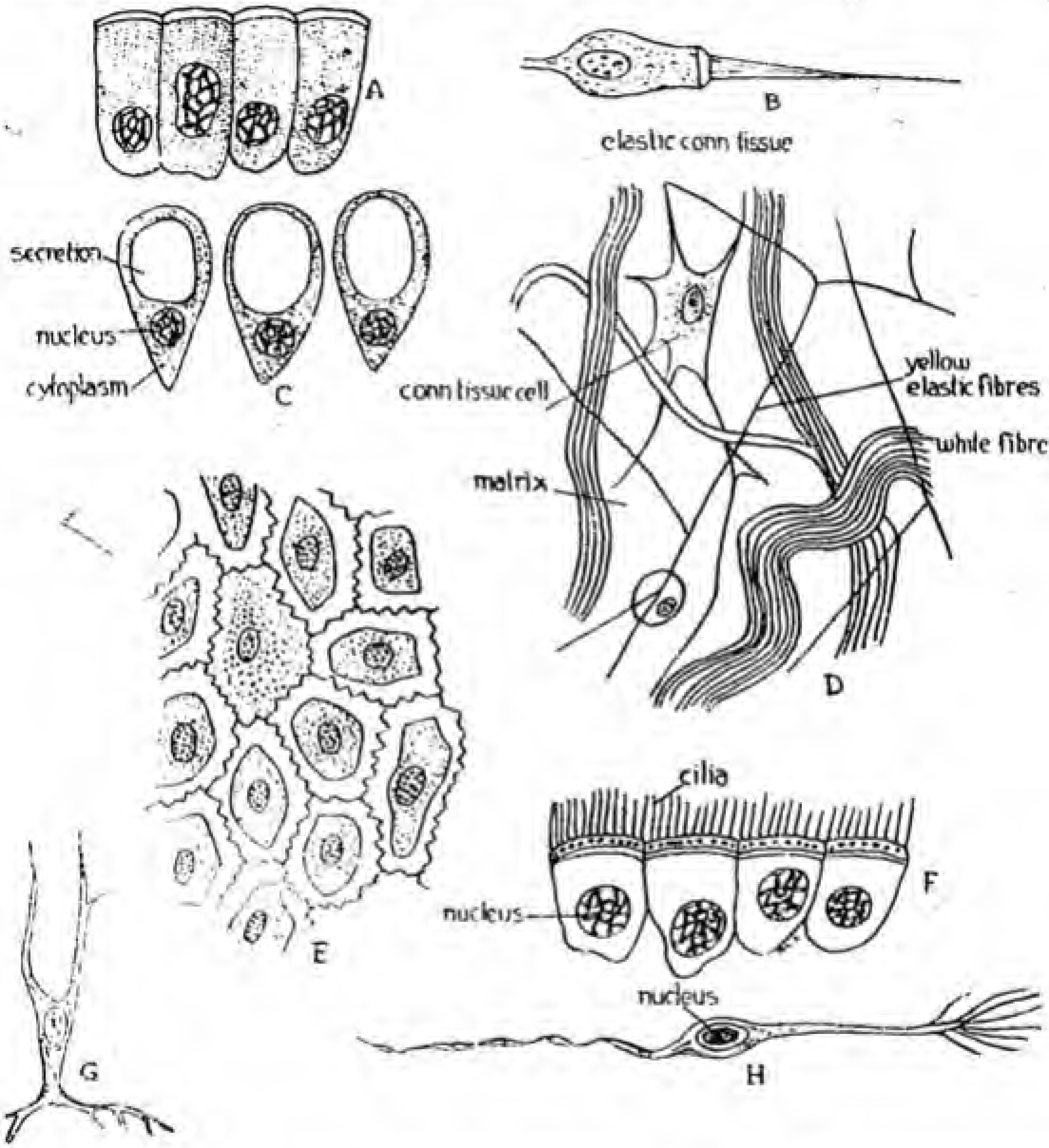


FIG. 101. Tissues of the frog. A. Columnar epithelium. B. Sensory epithelium; auditory hair cell from the anterior ampulla of the internal ear of frog. C. Glandular epithelial cell. D. Areolar connective tissue. E. Squamous epithelium. F. Ciliated epithelium. G. Sensory epithelial cell: gustatory cell from the tongue of frog. H. Sensory epithelial cell from the nose of frog.

material. The most important function of the epithelial tissue is to serve as a protective envelope and to form a lining for hollow spaces. Among the other functions of the epithelia are absorption, secretion and excretion.

Epithelia cover or line all organs. Only exceptionally, as for example in the teeth, an epithelium is absent.

On the basis of their function, epithelia are classified as: 1. protective epithelia, 2. glandular epithelia and 3. sensory epithelia.

Protective epithelium guards against injury and infection. It is further subdivided on structural basis as: 1. squamous epithelium, 2. columnar epithelium, 3. ciliated epithelium and 4. stratified epithelium.

SIMPLE OR SINGLE LAYERED EPITHELIUM

Squamous epithelium.—The squamous epithelium consists of a single layer of thin flat cells arranged like the tiles on a pavement. It is therefore also called ***pavement epithelium***. It is found in the ***peritoneum*** that lines the body cavity and in the ***endothelium*** on the inner surface of the blood vessels, heart, etc.

Columnar epithelium.—Columnar epithelium lines the cavity of the intestine of the frog. The cells are elongated and arranged adjacent to each other like a column of pillars. They rest on noncellular ***basement membrane***.

Ciliated epithelium.—Ciliated epithelium bears on its exposed surface hair-like protoplasmic processes called ***cilia***, which vibrate with a sort of lashing movement in one direction and thus set up currents in the surrounding liquid. Ciliated epithelium is found on the roof of the buccal cavity of the frog.

COMPOUND OR MULTI-LAYERED EPITHELIUM

Stratified epithelium.—The stratified epithelium has several layers of cells arranged one above the other in strata. It is found in the cornea of the eye and in the epidermis of the skin of the frog.

Glandular epithelium.—The glandular epithelium is specialized for secreting the products required for vital activities. Columnar cells secreting mucus and called ***goblet cells*** occur in the intestinal epithelium. Glandular epithelia occur in the stomach, intestine and skin of frog.

Sensory epithelium.—The special character of the sensory epithelium is that some of its cells, the ***sensory cells***, are connected with endings of the sensory nerves. The taste cells on the tongue and palate, the olfactory cells of the nasal chamber, the rods and cones of the retina of the eye, the hair cells of the membranous labyrinth of the ear, etc., are examples of sensory epithelial cells.

Sustentative tissue.—The sustentative tissue (Fig. 102) are a heterogenous group, having the chief function of supporting, connecting and binding

various internal organs. They differ from epithelial tissues by the presence of a large amount of intercellular material, produced by the tissue cells themselves. The intercellular material is really responsible for the functions of the sustentative tissue. There are four classes of sustentative tissues: 1. ***connective tissue***, 2. ***cartilage***, 3. ***bone***, and 4 ***adipose tissue***.

Connective tissue.—The connective tissue cells (Fig. 102) have the interspaces filled by other types of cells, for example, spleen cells, for which they form a support and a sort of frame-work. The intercellular space may also be filled by fibres and such a connective tissue serves for binding the skin of the frog to the muscles beneath. The fibres are white in tendons by which muscles are attached to bones.

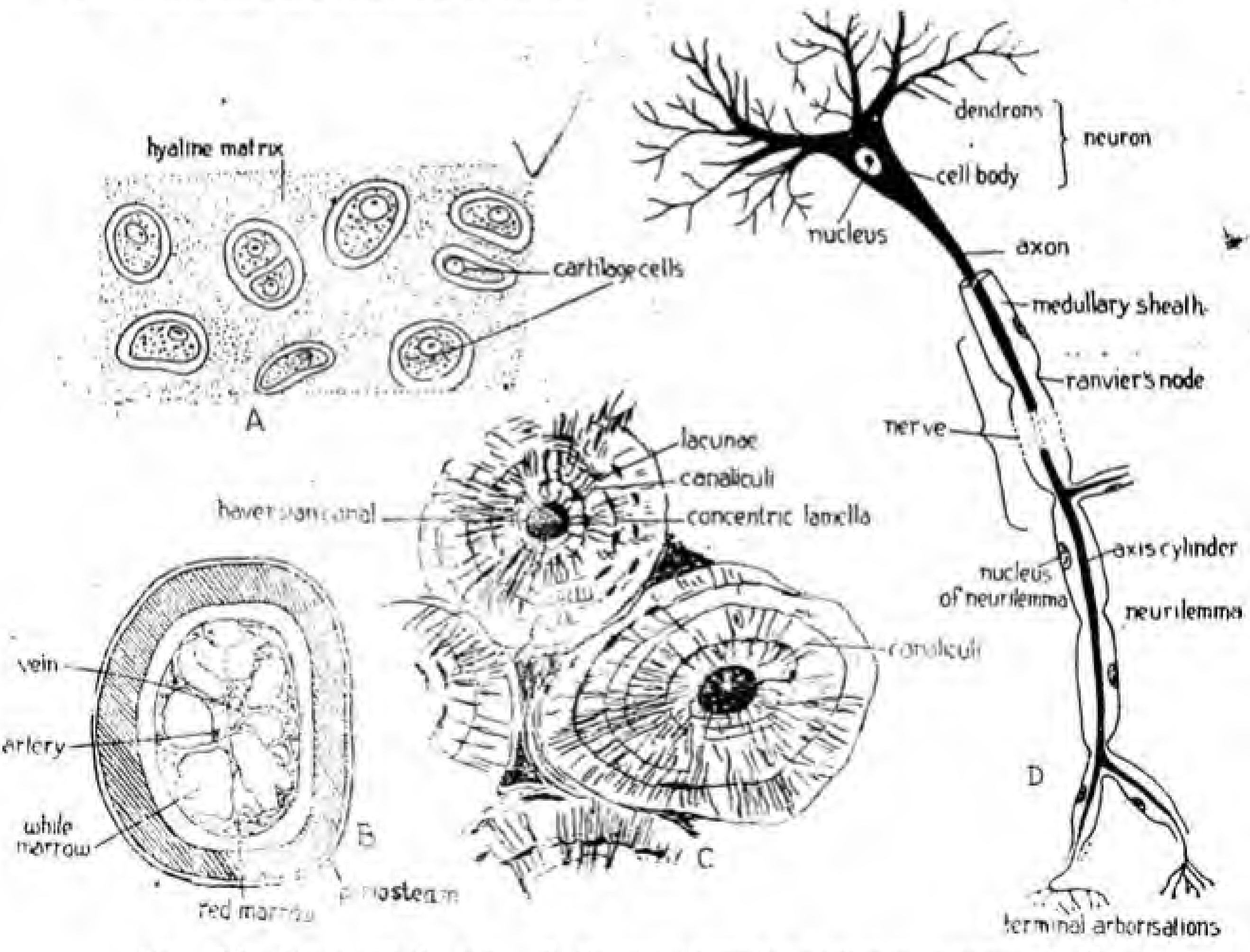


FIG. 102. Tissues of the frog A. Section through hyaline cartilage. B. Transverse section through femur after decalcification, , C. Transverse section through bone of rat. D Neuron and longitudinal section through a nerve.

Cartilage.—The cartilage cells are more or less rounded and scattered in lacunae or interspaces in the noncellular elastic gelatinous martix. In ***hyaline cartilage*** the martix is translucent; hyaline cartilage occurs

at the ends of long bones, in the larynx, hyoid and the tip of suprascapula. In ***calcified cartilage***, granules of calcium carbonate are deposited in the gelatinous matrix. The greater part of the suprascapula of the frog is of calcified cartilage. In ***fibrous cartilage*** white or yellow fibres occur in the matrix.

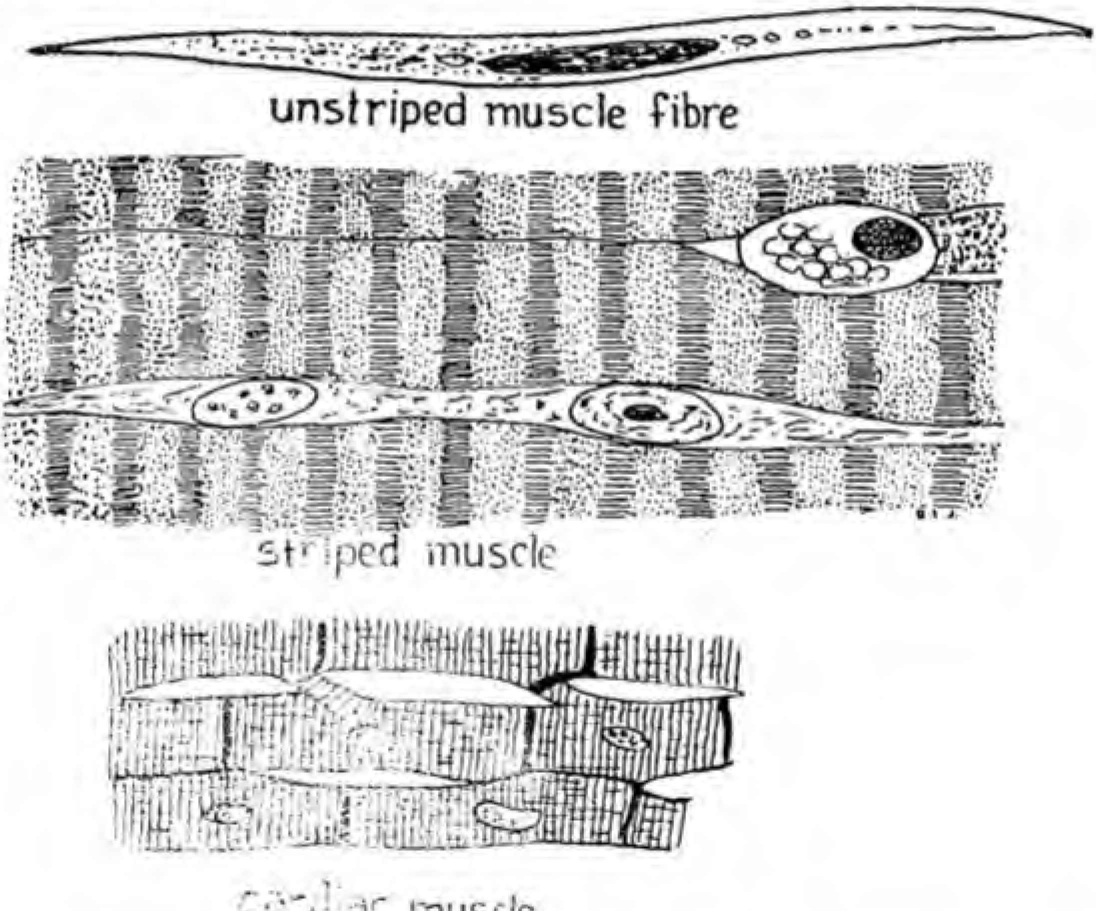
Bone.—The bone is the most complex of connective tissues. It consists of very hard matrix, heavily impregnated with calcium phosphate and calcium carbonate, in addition to traces of salts of fluorine, chlorine and magnesium. The matrix contains numerous irregular lacunae enclosing the ***bone cell***. In the matrix there are also ***Haversian canals*** containing arteries, veins and nerves. The Haversian canals are surrounded by rows of lacunae. These lacunae communicate with the Haversian canals and with one another by ***canaliculi***. Long bones, for example, the femur, have a central cavity filled with bone marrow. A bone is quite distinct from a calcified cartilage.

Bones are of two types : ***cancellous*** (spongy) and ***compact***. Haversian canals are lacking in a cancellous bone but the bone is spongy due to the presence of irregular ***trabeculae***. Example of a cancellous bone is the flat bones of the skull. The compact bones, for example, the long bones, show the typical Haversian canals, canaliculi, etc.

Adipose tissue.—In adipose tissue there is no intercellular material. Large drops of neutral fat are surrounded by cytoplasm. The fat cells often form lobules of vesicles made of thin noncellular membrane.

Muscular tissue.—The muscular or contractile tissue (Fig 103) consists of ***muscle cells***. Smooth or nonstriated muscles occur in the walls of the alimentary canal, arteries and urinary bladder of the frog. The cells are elongate and fusiform and are arranged in sheets and held together by fibrous connective tissue. The striated skeletal muscle fibres are gathered in bundles by connective tissue called ***endomysin***. Several bundles are bound together by ***perimysium*** into a muscle. The individual fibres are covered by an elastic membrane, the ***sarcolemma***. The fibres are longer than in the smooth muscles. Under the microscope each fibre shows alternate bands of dark and light stripes. In the cardiac muscles the fibres are striated and branched and anastomosed to form an interconnecting network. The protoplasm is granular. The striations are irregular and closer together and the myofibrils coarser than in striated muscles. The nuclei are also larger.

Nervous tissue.—The ***neuron*** or the nerve cell (Fig. 102) has cell body with a nucleus. There are one or two conducting protoplasmic processes—the dendrons and axons. In the cytoplasm there are irregular threads, the ***neurofibrils***, running in all directions and extending into the nerves. The granules staining deeply with aniline dyes constitute the ***Nissel bodies*** in the cytoplasm and dendrons but not in the axons. A ***monopolar neuron*** has a single process from the cell body. This soon divides into two, one branch corresponds to dendron and the other axon. ***Bipolar neuron*** has one axon and one dendron. In ***multipolar neurons*** there are many dendrons but always only one axon. The dendrons are short and branched close to the cell body like a tree. The axon sometimes gives off collateral fibres.



[illegible] Muscular tissue of frog.

A nerve [illegible] dendrons and axons. Nerves are of two kinds, ***white*** or [illegible] ***fibres*** and ***grey*** or ***non-medullated fibres***. The medullated fibres largely constitute the white matter of the brain and spinal cord and cranial and spinal nerves. They are called white, because in the dead fibres, the fatty substance which forms their sheath, turns

white. The conducting part is the ***axis-cylinder*** and the insulating sheath is ***myelin*** or ***medullary substance.*** Myelin is a fat, ***lecithin,*** containing phosphorus. Externally the nerve is ensheathed by ***neurilemma.*** The medullary sheath is not a continuous covering but at regular intervals it is constricted into ***nodes of Ranvier.***

The non-medullated nerve fibres are found chiefly in the autonomic nervous system but often in the cranial and spinal nerves also. They are transparent fibres, without any surrounding sheath.

MINUTE STRUCTURE OF IMPORTANT ORGANS OF THE FROG

Integument.—The integument or skin of the frog (Fig. 104) consists of two layers : a superficial ***epidermis*** and a deeper ***dermis.***

Epidermis.—The epidermis is composed of several layers of cells, grouped into a ***stratum corneum*** and a ***stratum germinativum.*** The stratum corneum is on the surface and is a squamous epithelium. The stratum germinativum is composed of several layers of cells forming a stratified epithelium. The upper layers of cells are polygonal and the innermost layer is composed of columnar cells. This layer is the ***stratum malpighium.*** The cells of the stratum germinativum are interconnected by fine protoplasmic threads or ***intercellular bridges. Chroma-tophores*** or pigment cells occur in the epidermis. There are nerve endings in the lower layers of the epidermis. The ducts of glands from the dermis beneath pass through the epidermis to open on the outer surface.

Dermis.—The dermis or ***corium*** is composed of the outer ***stratum spongiosum*** and inner ***stratum compactum.*** In both these layers white non-elastic and yellow elastic connective tissue fibres occur. The dermis is elevated into irregular papillae, in which the touch corpuscles are found. This layer is richly supplied with blood vessels and lymph spaces. A relatively large number of chromatophores occur in the spongy layer. Below the dermis, loose connective tissue encloses lymyh spaces and attaches the skin to the underlying parts.

The skin of the frog contains simple ***alveolar glands.*** The wall of the spherical space, the ***alveolus,*** is lined by a single layer of glandular cells. The alveolus has a duct opening on the outer surface of the skin. These are the mucus secreting and poison glands.

Stomach.—The stomach wall (Fig. 105) is composed of 1. peritoneum or serosa, 2. turica muscularis 3. submucosa and 4. mucosa.

The ***tunica muscularis*** or the muscular coat consists of a longitudinal and a circular layer of unstriated involuntary muscles. The circular layer is thicker than the longitudinal layer. The ***submucosa*** is well deve-

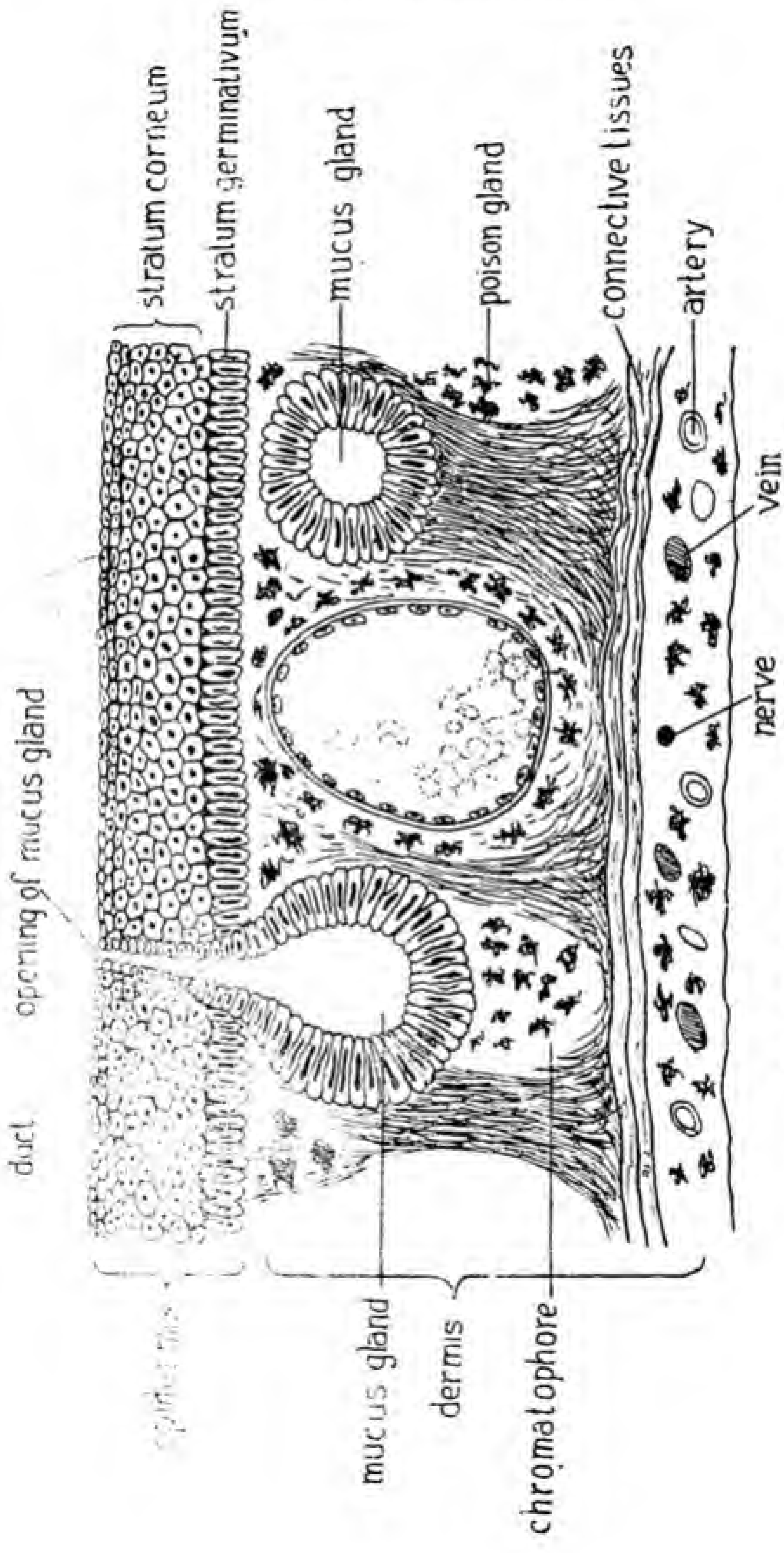


Fig. 104. Vertical section through the skin of frog

loped and is composed of loose connective tissue, in which blood vessels and lymphatics ramify. On the inner surface it possesses a ***muscularis***

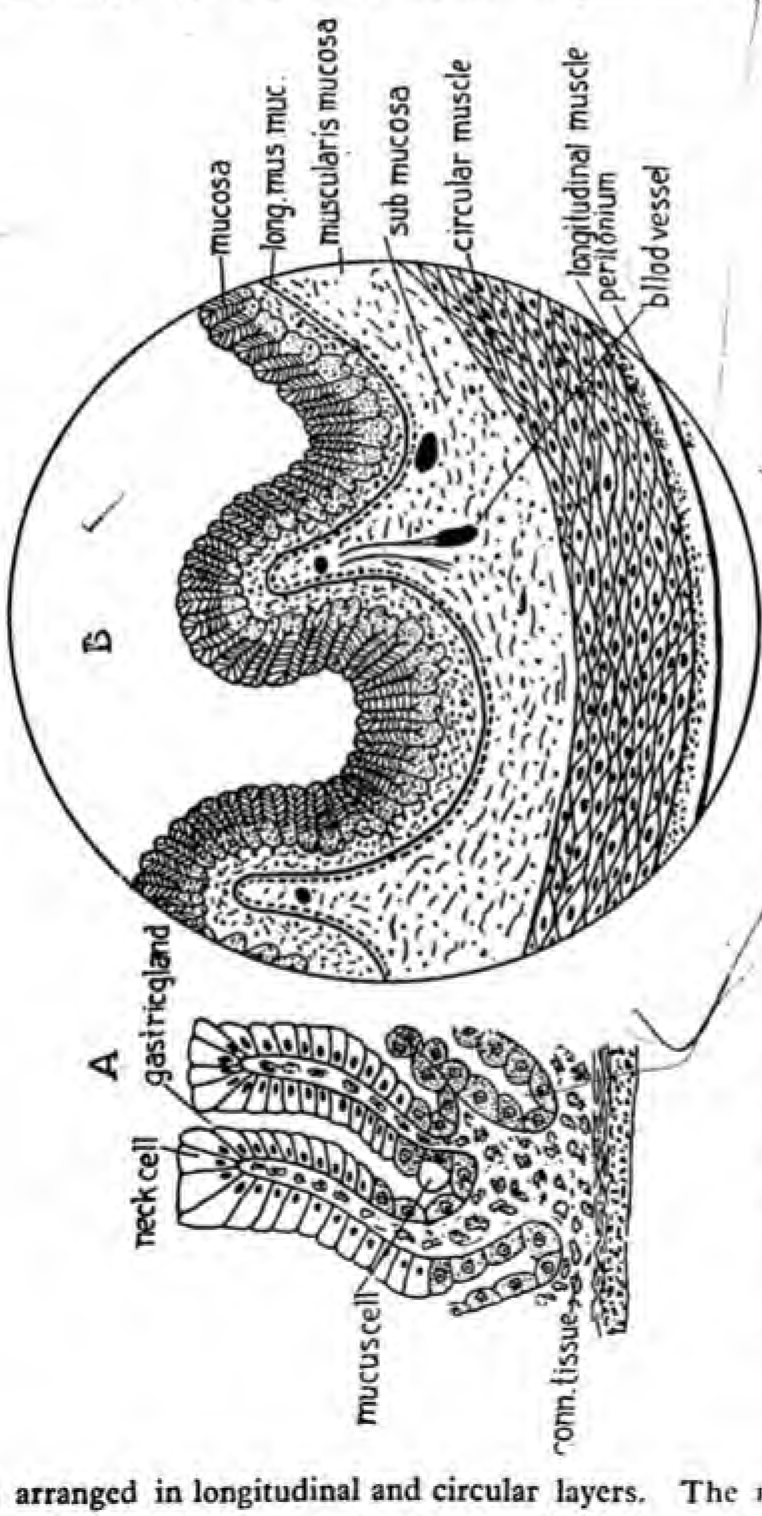


FIG. 105. B. Part of transverse section through the stomach of frog. A. A small portion of the mucosa very highly magnified.

mucosa arranged in longitudinal and circular layers. The mucosa is rich in tubular glands. This is a glandular epithelium. It is thrown into numerous longitudinal folds and each fold is covered by numerous finger-

like elevations. Ciliated epithelial cells occur on the inner surface. The glandular cells are modified columnar cells, with a broad free and a narrow inner end. These are the so-called ***goblet cells,*** which secrete mucus. Tubular gland cells secrete the gastric juice.

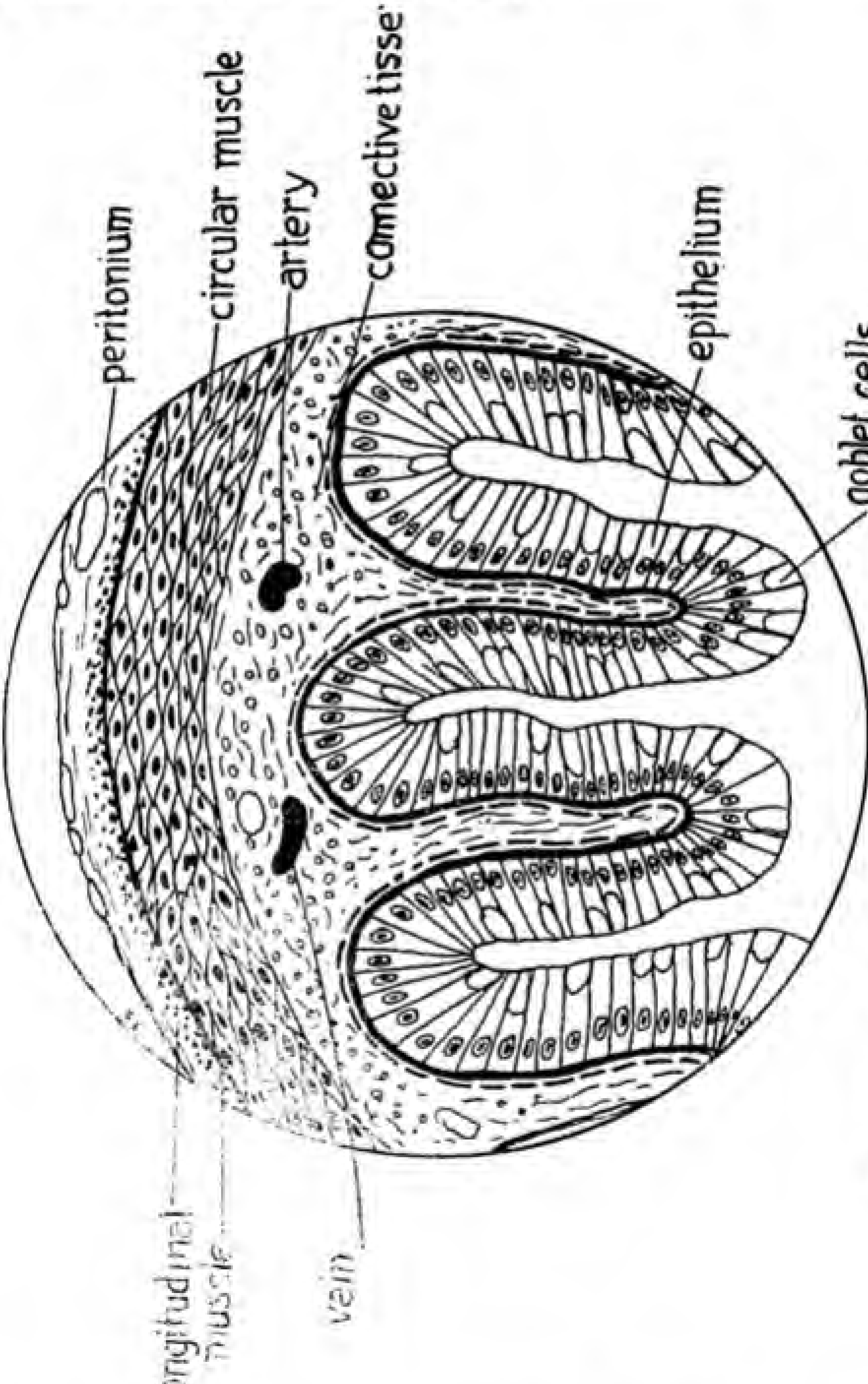


FIG. 106. Part of transverse section through the small intestine of frog.

Intestine.—The wall of the intestine (Fig. 106) is also composed of the same four layers as the stomach, but the submucosa is relatively thin and the mucosa presents certain peculiarities. In the duodenum the mucosa is thrown

into semilunar valve-like folds. In the small intestine the mucosa presents network of irregular folds and posteriorly regular longitudinal folds. The mucosa is covered by columnar epithelium, with the cells on a basement membrane. There is a thin layer of connective tissue between the epithelium and the muscularis mucosa. Goblet cells are abundant. Blood capillaries and lymphatics form a network on the inner surface of the muscularis mucosa.

Liver.—The liver (Fig. 107) is composed of 1. peritoneum, 2. fibrous covering, 3. hepatic cells, 4. bile canals and 5. blood vessels.

The peritoneum encloses the liver almost completely. The fibrous coat is thin and is composed of connective tissue fibres. The hepatic cells or the ***liver parenchyma*** are large compressed spheres or polygons. They often contain granules of glycogen.

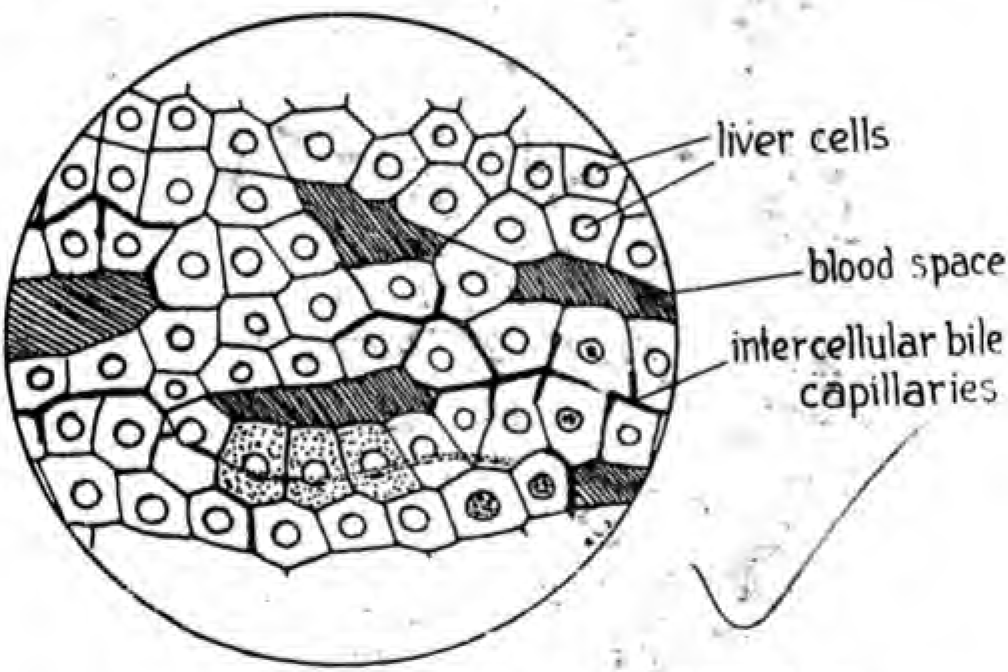


FIG. 107. Part of section through the liver of frog.

Pancreas—Connective tissue encloses a number of lobes, composed in turn of lobules. Each lobule comprises tubes lined by a single layer of glandular epithelial cells. These are the ***alveolar cells***, the secretions of which are removed by ducts. There is yet another type of gland cells, the ***islet cells*** or the ***islets of Longerhans***, which have no ducts. These are scattered in between the alveolar gland cells.

Kidney.—The kidney (Fig. 108) is ensheathed by a thin fibrous tissue, which sends ***trabeculae*** into the interior to support the blood vessels and

gland cells. The uriniferous tubules are bound together by fibrous connective tissue. The ***malpighian capsules*** are composed of loops of an artery, the ***glomerulus***, enclosed by a ***Bowman's capsule*** (Fig. 69). The outer wall of the Bowman's capsule continues as a tubule, which becomes convoluted at first, then forms a loop (loops of Henle) and opens into a collecting duct. The latter runs across near the dorsal surface outwards to open into the ureter. The wall of Bowman's capsule is composed of thin flat cells; in the tube the cells are columnar. Immediately after the capsule, the tube cells are ciliated.

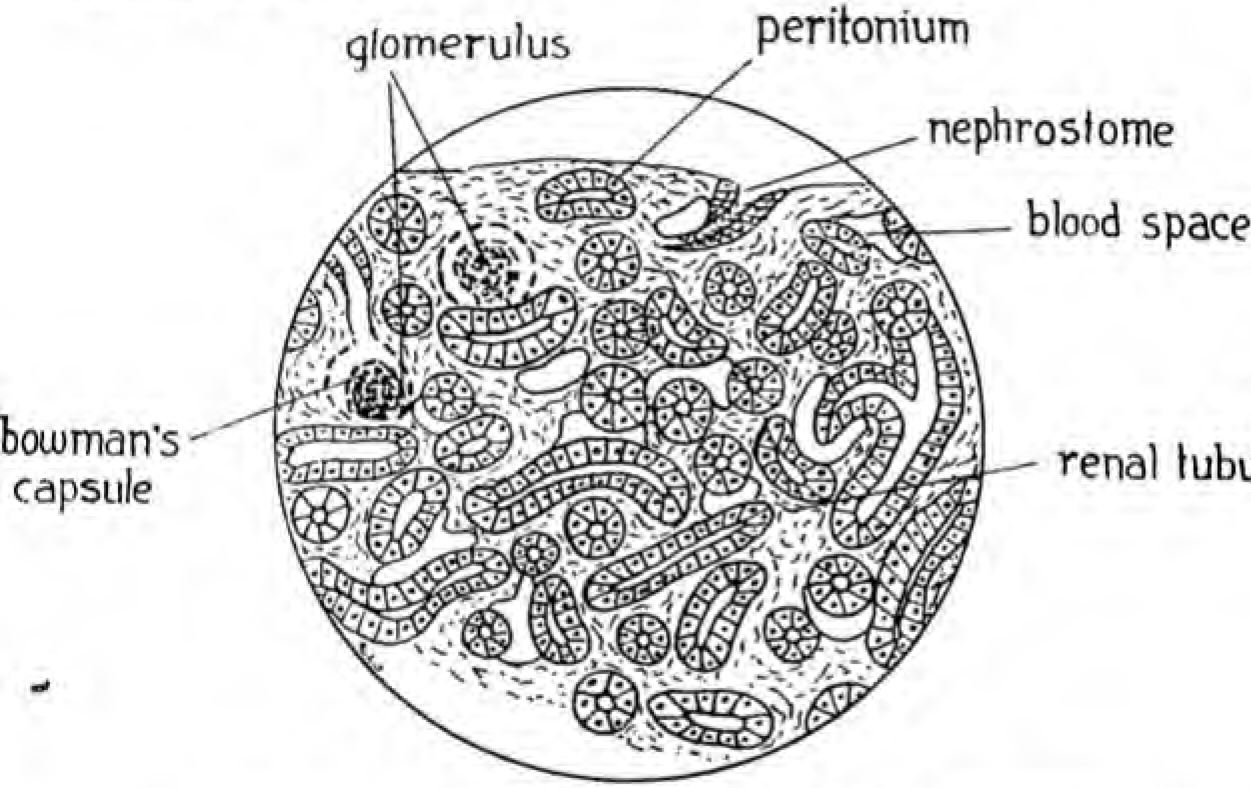


FIG. 108. Transverse section through part of the kidney of frog.

Spleen.—The spleen has an outer peritoneal coat, beneath which lies a fibrous coat. The latter sends in trabeculae to form a meshwork supporting the spleen pulp, spleen corpuscles, blood corpuscles and pigment cells.

Testis.—The testis (Fig. 109) is ensheathed by thin connective tissue beneath the peritoneum. The peritoneum sends in supporting trabeculae, thus giving rise to lobules. Seminiferous tubules arise from an irregular sinus and are lined by germinal epithelium with spermatogonia, spermatocytes and sperms in the lumen.

Ovary.—The peritoneal covering of the ovary is composed of isolated ciliated cells. Beneath the peritoneum is a thin layer of connective tissue. The connective tissue sends in septa, to which the ova are attached. Between

the peritoneum and the connective tissue is the germinal epithelium

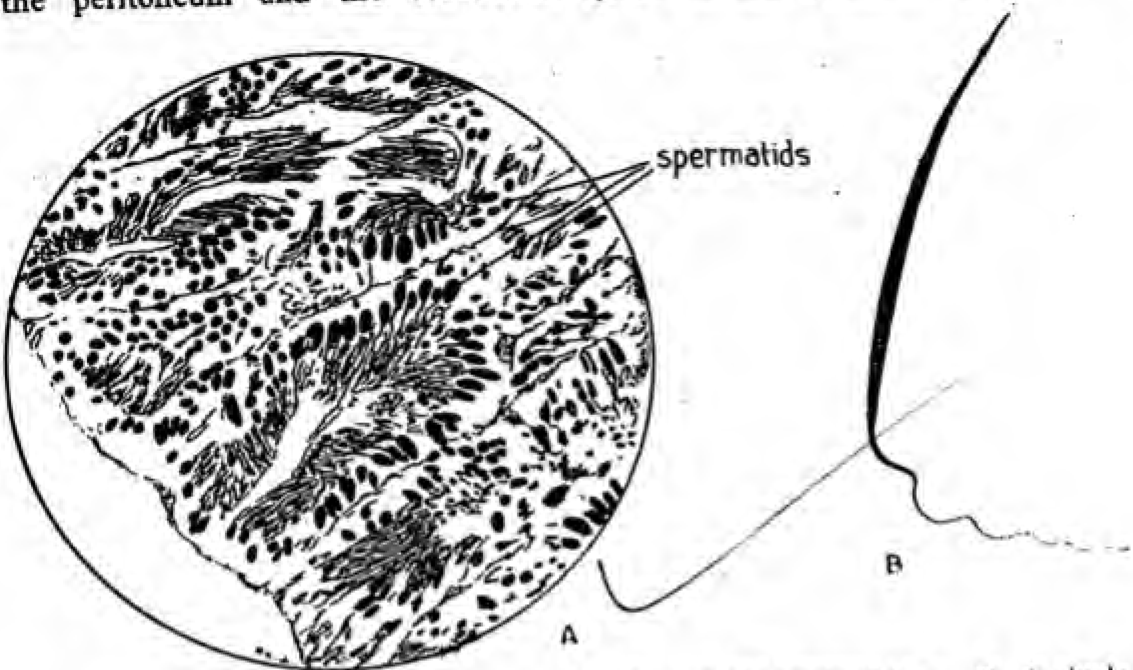


FIG. 109. A. Part of transverse section through the testis of frog. B. A single spermatozoen of frog.

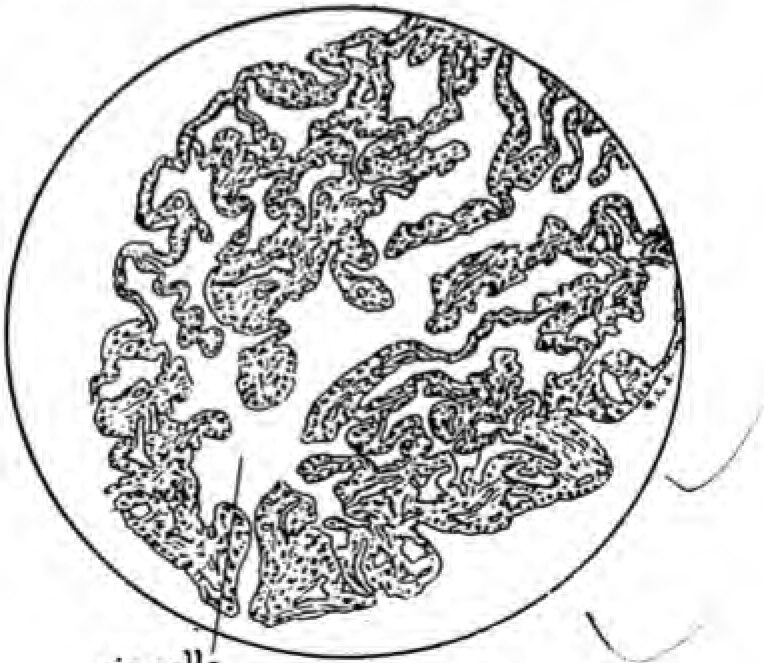


FIG. 110. Part of transverse section through the lung of frog.

composed of rounded cells. Each ovum is contained in a follicle having connective tissue coat.

Lungs – The lungs (Fig. 110) are composed of muscular, connective and epithelial tissues. The muscular tissue is present in large bands forming a net-work. These are smooth muscle fibres. The connective tissue is relatively not abundant: it comprises many yellow elastic fibres. The epithelium of the lungs is variable. The borders of alveoli have columnar ciliated epithelium. The alveoli are lined by polygonal cells. The epithelium rests on basement membrane.

RESUMÉ

1. The skeleton is the frame-work of the body. It protects various organs and gives attachment to muscles.

2. The skeleton of the frog is composed of cartilages, calcified cartilages and bones.

3. The skeletal system comprises an axial and an appendicular portion.

4. The vertebral column is composed of nine vertebrae and the urostyle. A typical vertebra comprises a bony arch on a centrum, with transverse and neural processes. The atlas has no transverse processes. The sacral vertebra presents two concavities behind for articulation with the urostyle.

5. The large skull includes a small cranium and large jaws. There are two occipital condyles. The lower jaw bone is articulated mainly by the quadrate cartilage to the skull.

6. The pectoral girdle receives the fore limbs. It comprises mainly suprascapula, scapula and coracoid.

7. The pelvic girdle, that receives the hind limbs, articulates directly to the sacral vertebra.

8 The fore and hindlimbs comprise the same set of bones, differing only proportions. They are serially homologous organs.

9 The muscles are of two chief types: smooth and striated. They are generally arranged in antagonistic pairs that bring about various kinds of movements.

10. The nervous system forms the conducting and co-ordinating mechanism of the body. It includes the brain, the spinal cord, the paired nerves that arise from those two, and the autonomic centres. The brain and the cord are hollow structures.

11. The neuron is the unit of the nervous system.

12. It is a specialized cell that has insulated conducting processes axon and dendron

13. A reflex arc is formed by the dendron of a sensory neuron, its axon in synapse with the dendron of a motor neuron and the axon of the latter ending usually in a muscle. Such an arrangement– produces an automatic involuntary response to some stimulus.

14. The endocrine organs release various harmones into the general blood stream and serve as the great "inter-locking chemical directorate-general of the body."

15. The cell that is the unit of the body, is a bit of protoplasm with a nucleus. It is modified into various tissues for different functions.

16. Cells divide by mitosis or amitosis. Mitosis comprises complicated nuclear changes, in which are recognized prophase, metaphase, anaphase and telophase.

17. The tissues are classified as epithelial, sustentative, muscular and nervous.

18. The epithelial tissue lacks intercellular material and serves as protective covering and as absorbing or secreting surfaces.

19 The sustentative tissue supports, connects or binds internal organs and has a considerable intercellular matrix. Connective tissue, cartilage, bone, etc., are examples.

20. The skin consists of epidermis and dermis. Chromatophores occur in the former.

CHAPTER V

THE FROG *(continued)*

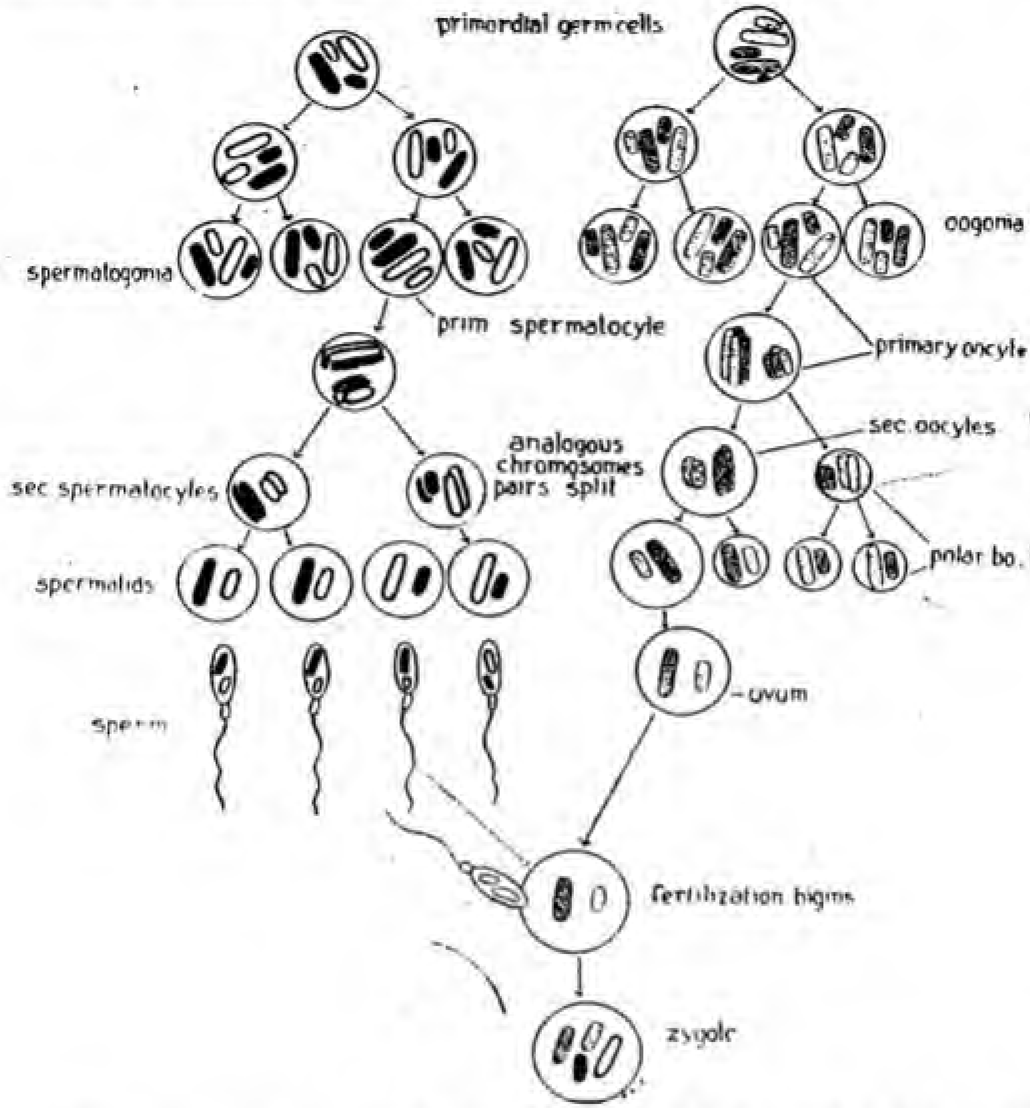
13. REPRODUCTION AND DEVELOPMENT

Reproduction.— The frog reproduces by the ***sexual method.*** There are two sexes – female and male. During the breeding season, that coincides with the rains, the female frog discharges her ova into water. The male climbs over the female and sheds his sperms on the eggs. There is usually a rough and primitive sort of courtship. The males sing loudly and often fight among themselves over the lady-love. The successful and the loudest croaking male is accepted by the Miss Frog. The eggs are covered in a gelatinous protective mass, which swells up in water and forms an effective protection for the eggs, that are otherwise left to their fate. They develop in the water by the heat of the sun and of course exposed to numerous enemies and natural catastrophies. Considering the various dangers to which the eggs are exposed, it is really a wonder that there are frogs at all. Out of hundreds and thousands of eggs laid, hardly one or two ultimately reach maturity.

Development.— All animals begin their life at first as a minute single cell, the ***ovum.*** This cell repeatedly divides and forms two or three layers of epithelia, which give rise to all the complicated tissues and organs that make up the animal. The series of changes which the ovum undergoes till it becomes the adult animal is called ***development.*** Although it is an unbroken series of changes, each more complex than the one before, two distinct stages are recognized in the frog, viz. the ***embryonic*** and the ***postembryonic.*** The embryonic development includes the changes within the ovum and the postembryonic changes comprise the development after the young animal escapes from the ovum till it becomes an adult frog. The ovum is produced by the female frog. Before however the ovum can begin developing into the frog, it must be united with the sperm from the male, i.e. it must be fertilized. The ovum and the sperm are ***gametes*** or the uniting cells.

Gametogenesis.—Gametogenes (Fig. 111) is the process of maturation of the germ cells into the gametes. The cells which are destined to give rise to the gametes are called ***primordial germ cells.*** The primordial germ cells contain the diploid number of chromosomes characteristic of the animal. During the gametogenesis this number is reduced exactly

to half. When the male and the female gametes unite together in fertilization, the number of chromosomes become deploid again.



[illegible] of gametogenesis in animals by maturation (reduction) division [illegible] pairs of chromosomes split lengthwise and give rise [illegible] in the gametes Fertilization restores the diploid number.

/ Oogenesis—Oogenesis is the maturation of the primordial germ cell into the ovum. The primordial germ cells divide rapidly by mitosis and give rise to ***oogonia***. The oogonia enlarge by deposit of ***yolk*** or reserve food material and thus become ***primary oocytes.*** The oocytes then divide twice. The first division gives rise to two unequal cells: a large ***secondary oocyte*** and a very small ***first polar body.*** The secondary oocyte again divides into two unequal cells: a large ***ootid*** and a small ***second polar body***. The ootid is the mature ***ovum*** and the polar bodies degenerate sooner or later. The ootid contains half the number of chromosomes characteristic of frog.

Spermatogenesis.—The spermatogenesis is the maturation of the primordial germ cell into the sperm. The primordial germ cells repeatedly divide by mitosis and give rise to several ***spermatogonia.*** The spermatogonia produce by further division a very large number of ***primary spermatocytes*** The primary spermatocytes divide and produce two equal-sized ***secondary spermatocytes.*** Each of these again divides equally to produce two ***spermatids.*** Thus each primary spermatocyte gives rise to four spermatids, which contain each half number of chromosomes. The nucleus of the spermatid moves into the head of the ***spermatozoen*** or sperm (Fig. 109) and the cytoplasm gives rise to the ***middle piece*** and ***tail*** of the sperm. The sperm is capable of locomotion by the lashing movements of the tail.

Fertilization.—Fertilization is the fusion of the sperm and the ovum. The frog's ovum is fertilized outside the body of the mother—the female which produces the ovum. The ova are discharged into the water by the female frog and the male sheds the sperms on them. A single sperm alone enters each ovum. After the entry of this sperm, the membrane of the ovum separates from the egg cytoplasm, leaving a clear fluid between and thus prevents the entry of any more sperms. The sperm which has entered the ovum now looses its tail and the head becomes transformed into the ***male nucleus.*** The nucleus of the ovum is now called ***female nucleus.*** The two nuclei approach each other slowly and finally they fuse with each other to form a single ***zygote nucleus.*** The ovum now becomes the ***zygote*** or the so-called " egg ". It is this fusion of the male and female nuclei which is strictly speaking " fertilization " and not the mere entry of the sperm into the ovum.

Embryonic development—The zygote is the starting point for embryonic development. The zygote is a single cell formed by the union of a male and a female cell. The zygote is the largest cell in the body of the frog and out of this single cell the future frog is destined to develop. The egg of the frog is rich in yolk material stored up by the mother. The yolk is concentrated in the ***vegetative pole*** in contradistinction to the darker upper ***animal pole,*** or the zygote cytoplasm proper. Such an egg is called a ***polar differentiated telolecithal*** egg.

During the embryonic development of the frog the following events take place: 1. ***cleavage*** or segmentation, 2. ***blastulation,*** 3. ***gastrulation,*** 4. ***organogenesis*** and 5. ***histological differentiation.***

Segmentation—The immediate result of fertilization is that the zygote undergoes repeated mitotic divisions. It divides into two daughter

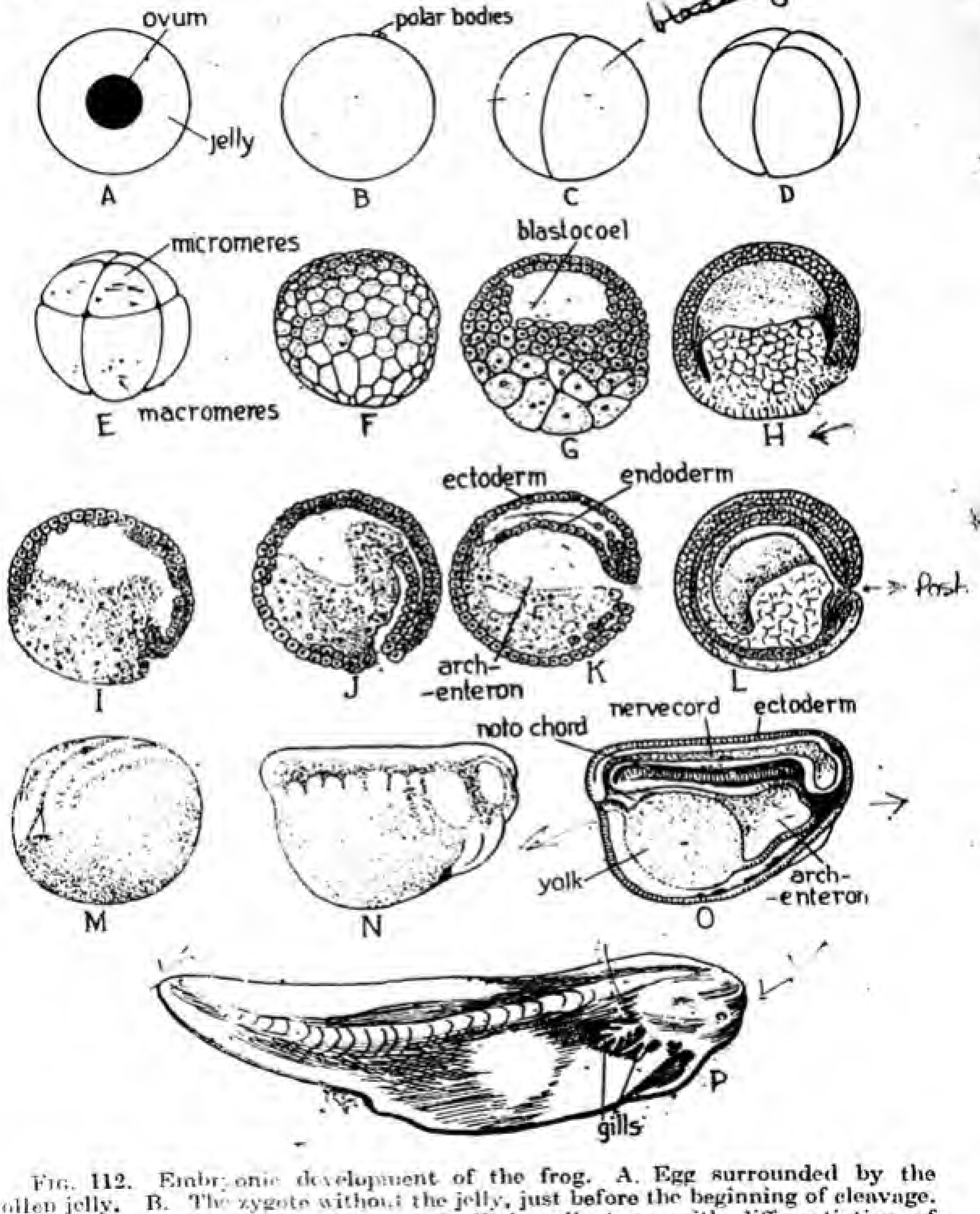


FIG. 112. Embryonic development of the frog. A. Egg surrounded by the swollen jelly. B. The zygote without the jelly, just before the beginning of cleavage. C. Two-cell stage. D. Four-cell stage. E. Eight-cell stage, with differentiation of micromeres and macromeres. F. Blastula. G. Section through the blastula. H. Beginning of gastrulation. I-L. Successive stages of the gastrula in section. M. Surface view of the gastrula, showing the blastopore closed. N. Late embryo with gill slits and mesoblastic somites. O. Longitudinal section through late embryo. P. Young tadpole with paired external gills.

cells; each of these divide into two, thus giving rise to four grand-daughter cells; these four again divide and give rise to eight, the eight divide into sixteen and so on in geometrical progression. This process of mitotic division of the zygote is called ***cleavage*** or ***segmentation.***

The first segmentation divides the frog's egg completely into two equal halves called ***blastomeres.*** The segmentation is thus ***total*** or ***holoblastic.*** A zygote which undergoes total cleavage is also described as holoblastic. This first segmentation takes place in the same plane in which the male and female nuclei approached each other before fertilization. The second cleavage takes place at right angles to the first cleavage but still in the same vertical or meridional plane. The third segmentation takes place horizontally and nearer the animal pole, so that the egg is now divided into four smaller pigmented cells above and four larger paler cells below. The smaller cells on the upper animal pole are called ***micromeres*** and the large on the vegetative pole are the ***macromeres.*** The succeeding segmentations take place more in the micromeres than the macromeres. The micromeres divide much faster than the macromeres, which comprise the yolk. The products of segmentation are thus of very unequal size and shape and therefore the segmentation is described as ***unequal.***

✓ **Blastulation.**—The segmentation of the zygote results in a very large number of pigmented micromeres forming a sort of a cap on the fewer unpigmented macromeres. Between them there is a hollow space called segmentation cavity or ***blastocoele.*** The whole structure is called a ***blastula.*** The blastocoele is filled with a fluid. The formation of the blastula marks the second stage of embryonic development.

Gastrulation.—The blastula consists of a mass of pigmented smaller cells on one hemisphere and larger unpigmented cells on the other. The blastula therefore always floats with the pigmented hemisphere on top. The pigmented micromeres gradually grow and reach almost to the equator of the blastula. In this marginal zone between the two hemispheres a small but conspicuous sickle-shaped deep groove appears. This groove is called ***primitive streak.*** It arises by the deep infolding or ***invagination*** of the micromere portion of the wall of the blastula by the rapid growth of micromere hemisphere. The groove elongates and also becomes deeper until finally it becomes circular. The micromeres at the same time grow over and enclose the macromeres, which are just left exposed as the ***yolk-plug*** within the circle of the primitive streak. The circle is now called the ***blastopore.*** The invagination

has also become so deep that the wall of the blastula becomes tucked-in into the blastocoele, which is nearly obliterated. A new cavity bounded by two membranes has thus been produced. This cavity is the rudiment of the alimentary canal of the future frog and is called ***archenteron*** or primitive gut. The roof of the archenteron is composed of two layers, the outer ***ectoderm*** or ***epiblast*** and the inner ***endoderm*** or ***hypoblast***. The yolk forms the floor of the archenteron. It is gradually digested within the archenteron and absorbed by the growing embryo. The zygote has thus become an ***embryo*** with a gut or ***gaster;*** it is therefore called a ***gastrula***. The series of changes of invagination and overgrowth or ***epiboly***, leading to the formation of the double-layered gastrula is termed ***gastrulation***. The gastrula of the frog is bilaterally symmetrical. Its blastopore indicates the place where the anus of the future adult will develop. There is as yet no mouth.

Organogenesis.—The epiblast and the hypoblast are the two ***germinal layers***. The gastrula is also described as the ***diploblastic*** stage of the embroynic development, because there are only two germinal layers. Soon a third germinal layer appears and the embryo becomes ***triploblastic***. All the organs are differentiated from these three germinal layers.

The organ which appears next is the nerve chord. The embryo elongates into the shape of a fish. The epiblast develops two lateral ridges along the median longitudinal line. A shallow groove thus appears in between the ridges. The edges of the groove are called ***neural folds***. The neural folds encircle the blastopore. They increase in height and fall inwards till they meet and fuse together enclosing a ***neural tube***. The cavity of the neural tube is destined to become the central canal of the future spinal cord. The anterior end of the neural tube enlarges into three hollow ***vesicles***, the fore, mid and hindbrain. While the neural tube is forming, the archenteron undergoes changes. The hypoblast or the roof of the archenteron now splits into two layers of cells except in the middle. The lower layer of these two is the secondary ***endoderm***, and the upper the ***mesoderm***.

The median part of the mesoderm separates from the lateral part and forms a solid rod, the ***notochord*** or ***chorda dorsalis*** lying below the nerve cord. The notochord appears first posteriorly and then extends forward. Round this the vertebral column of the frog is destined to develop. The embryo is now in the triploblastic stage. The mesoderm then forms thickened bands, the ***segmental bands*** on either side of

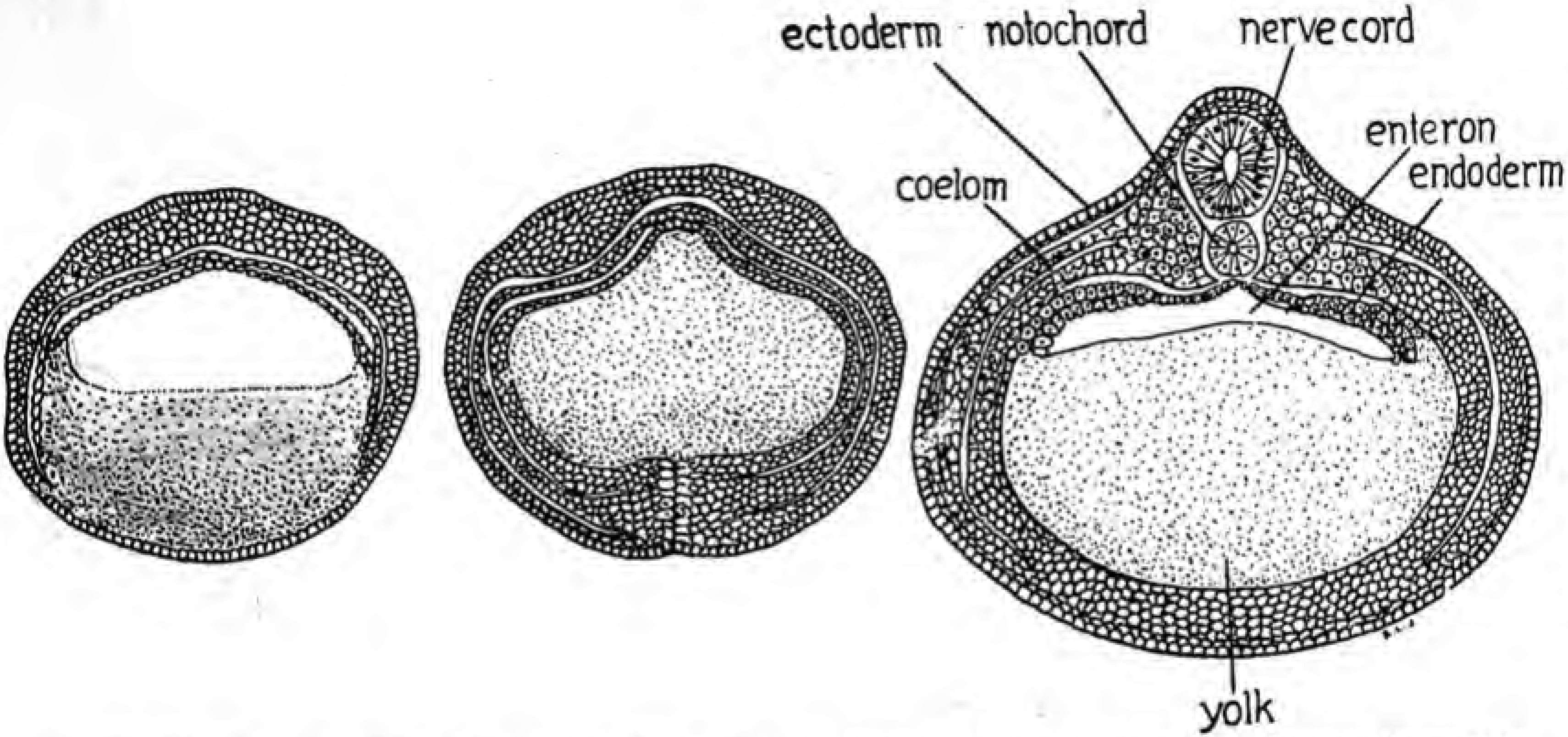


FIG. 113. Sections through the early embryos of the frog. A. Transverse section in the anterior part showing the ectoderm, endoderm and mesoderm. B. Horizontal section through the region of the blastopore. C. Transverse section in the middle of the embryo to show the neural tube, notochord, coelom, enteron and the diminishing yolk.

the notochord. The segmental bands divide into a lower ***splanchnic*** layer and an upper ***somatic*** layer. The intervening space is ***coelom*** or body cavity. The somatic layer gives rise to the segmental skeletal muscles and the splanchnic layer lines the gut. The endoderm now grows ventrally and completely encloses the fast diminishing yolk. The ectoderm forms an anterior pit, the ***stomodaeum***, on the ventral surface. The stomodaeum deepens and opens into the archenteron, thus forming a mouth Similarly a posterior ***proctodaeum*** gives rise to the anus. Liver develops as a hollow bulge from the ventral wall of the gut. The heart appears as a straight tube, which becomes twisted into a knot, forming the ventricle and auricles. External gills appear anteriorly and embryonic development is almost complete.

The various adult structures develop from the germinal layers as below.

ECTODERM

Nervous system, eye, ear, nasal cavity, epidermis of the skin and membrane bones of the skeleton.

ENDODERM

Lining of the digestive cavity, liver, pancreas and lining of the lungs.

MOSEDERM

Dermis of skin, cartilage bones of the skeleton, muscles, blood, heart, excretory system and reproductive organs.

Postembryonic development.—When the embryo has completed its development in the egg, a young frog does not hatch from it. A peculiar-looking fish-like immature creature or a ***larva*** comes out. This larva of the frog is called a ***tadpole***. It swims in the water by the lashing movement of its powerful and long tail. It feeds and as it grows, changes its shape and appearance several times before finally leaping out of the water as a frog. These changes of shape and structure of a larva before it becomes an adult comprise ***metamorphosis***.

The tadpole has horny lips surrounding the mouth. These lips are used for rasping the soft and succulent aquatic vegetation, which forms the food of the tadpole. The alimentary canal becomes elongated and coiled like a watch-spring. It has two pairs of ***gills*** and very soon a third pair of external gills develop. These gills are richly supplied by blood vessels and are the respiratory organs of the larva. The pharyngeal region of the alimentary canal develops paired pouch-like outgrowths, called ***gill pouches***. The gill pouches extend to the surface of the body and pierce

the skin, giving rise to ***gill slits***. Soon a fold of skin, the ***operculum*** extends and covers up the external gills and the gill slits ventrally and on the right, but leaving a small aperture, the ***spiracle***, on the left. A ***branchial chamber***, into which the gill slits open, is thus formed. The external gills soon degenerate and are replaced by internal gills. Water enters

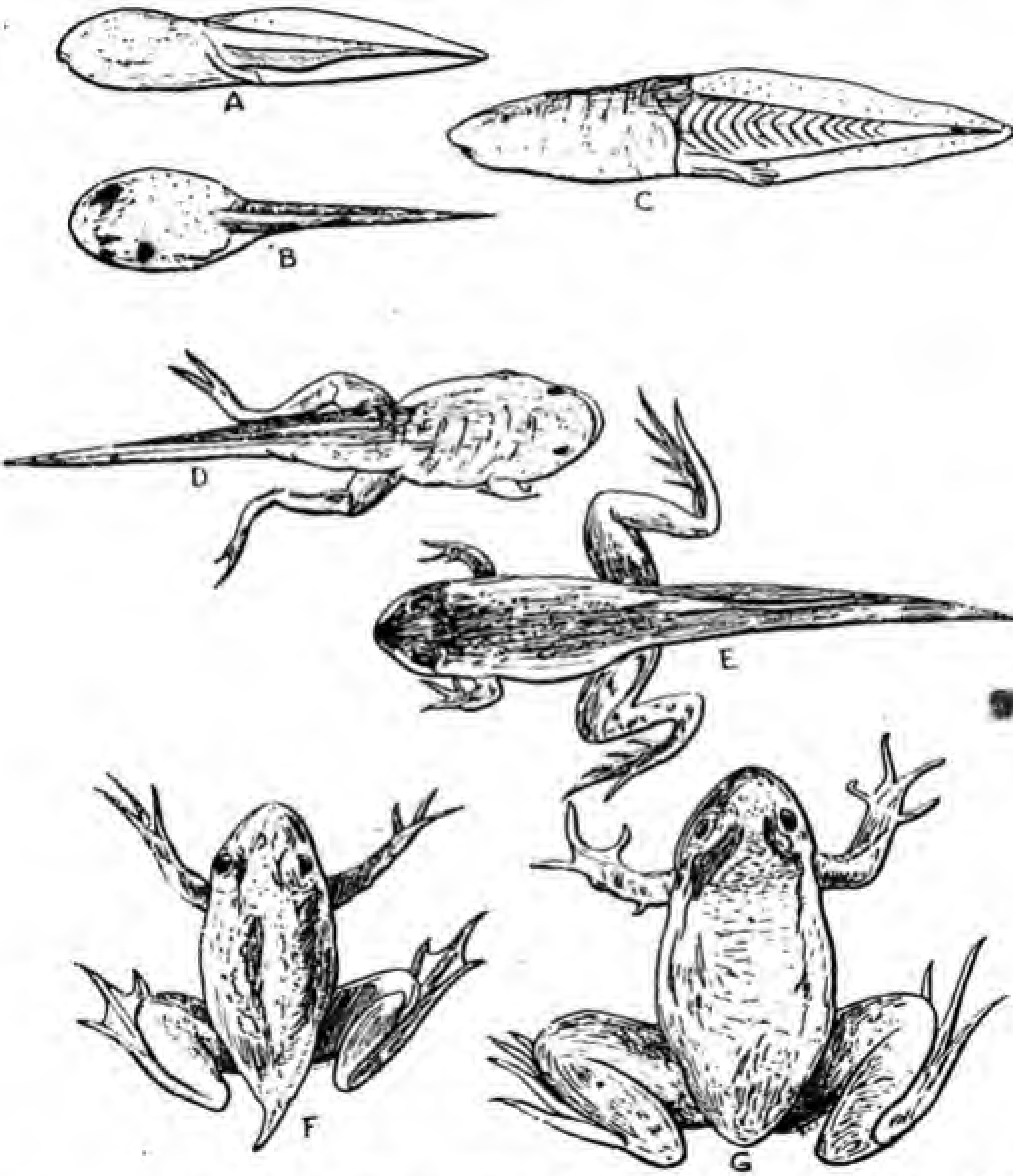


FIG. 114. Postembryonic stages of the frog. A-B. Young tadpoles. C. Tadpole with rudiments of hindlegs. D. Todpole with elongated hindlegs and rudiments of forelegs. E-F. Young tailed frogs. G. Young frog.

through the mouth, passes through the pharynx into the branchial pouches, washes the gills and escapes to the outside by the spiracle on the left. At this stage the tadpole is very much like a fish.

When the tadpole is about a month old, the hind limbs appear at the base of the tail as small stumps and gradually grow longer. The fore limbs, which develop before the hind limbs, remain hidden beneath the operculum long after the hindlimbs have already grown out.

The lungs, which appeared at a very early stage as a ventral pouch from the alimentary canal, now become functional. The tadpole, which can still breathe through its skin and by internal gills, occasionally rises to

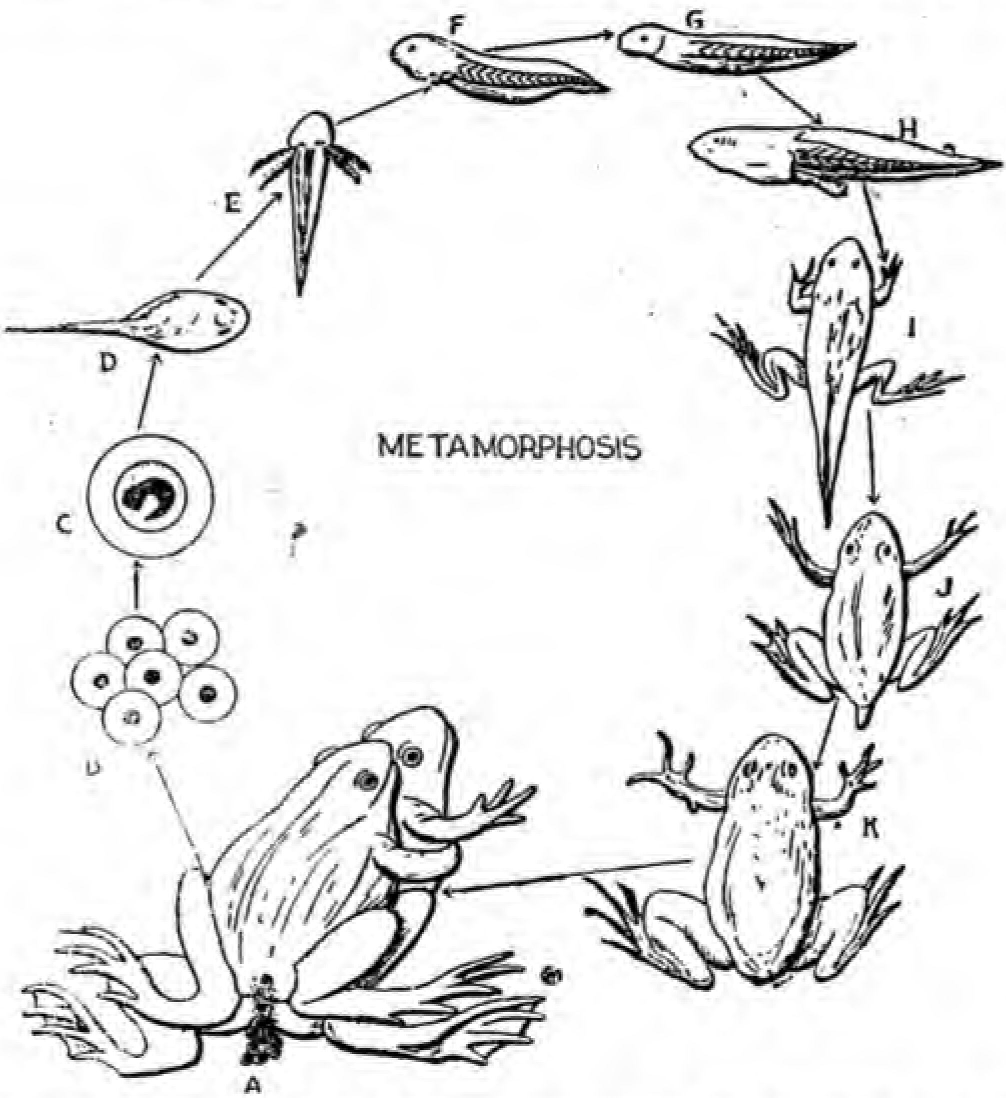


FIG. 115. Life cycle of the frog with metamorphosis. A. Adult male climbs over the female and sheds his sperm on the eggs she is discharging into the water. B. Mass of eggs enclosed in swollen jelly. C. Developing embryo. D-I. Stages of tadpoles. J. Tailed frog. K. Young frog.

the surface of the water in order to gulp in air into the lungs. Respiration in this is both ***aerial*** and ***aquatic.*** The tadpole now resembles the lungfishes and is therefore called ***dipnoan stage*** tadpole. The fore limbs pierce the operculum and grow out. The internal gills and the spiracle

disappear. Respiration becomes wholly aerial. We now have the four-legged, tailed frog, which leaves the water now and then to hop on the ground. It now changes its food and becomes a carnivore. The legs elongate and the tail progressively shortens, until the fully formed young frog appears. It reaches sexual maturity in one to three years.

Changes during metamorphosis.—The changes which the tadpole undergoes in its metamorphosis into the young frog are both external and internal. There are also changes in its habits.

EXTERNAL CHANGES

1. The limbless tadpole develops external gills and has an elongated tail.
2. Gill slits appear.
3. External gills are replaced by internal gills.
4. Hind limbs appear.
5. Fore limbs appear.
6. Internal gills appear.
7. Tail shortens.
8. Hind limbs elongate.
9. Tail is lost.

INTERNAL CHANGES

The internal changes are far more numerous and profound than the external ones. The main internal changes affect the respiratory and circulatory systems.

CHANGES IN THE RESPIRATORY SYSTEM.—Early respiration is by the general surface of the body. Just before the tadpole is hatched, the rudiments of the gills appear. The hypoblastic epithelium of the anterior part of the gut is evaginated as paired lateral outgrowths, viz. the ***gill pouches.*** Three anterior pairs of pouches develop first and are succeeded later by two more behind. Thus five pairs of ***branchial*** (=gill) pouches occur. These pouches grow outward and meet the epiblast. Six pairs of cartilagenous skeletal supports, the ***gill arches,*** develop to strengthen the pouches. The first pair of these is called the ***mandibular arch.*** Though now a skeletal support for a gill, it is destined later on to become one of the jaws of the frog. The second is the ***hyoid arch.*** The remaining are called the first, second, third and fourth gill arches; these degenerate in due course when the lungs develop. At the time the tadpole hatches, the first and second gill arches alone bear each a branched and highly vascular external gill. Later still, a similar gill develops on the third arch also. Finally with the formation of the gill slits

and of the operculum, these gills shrivel up and internal gills develop on the gill arches as in the fishes. The lungs appear early, in fact almost simultaneously with the hatching of the tadpole. They however remain small and functionless until after the formation of the internal gills. Gradually the latter disappear and the lungs become functional.

CHANGES IN THE CIRCULATORY SYSTEM.—Even before the hatching of the tadpole, the heart develops. It is, to begin with, an almost straight tube – merely a blood vessel lying below the alimentary canal. Soon however it

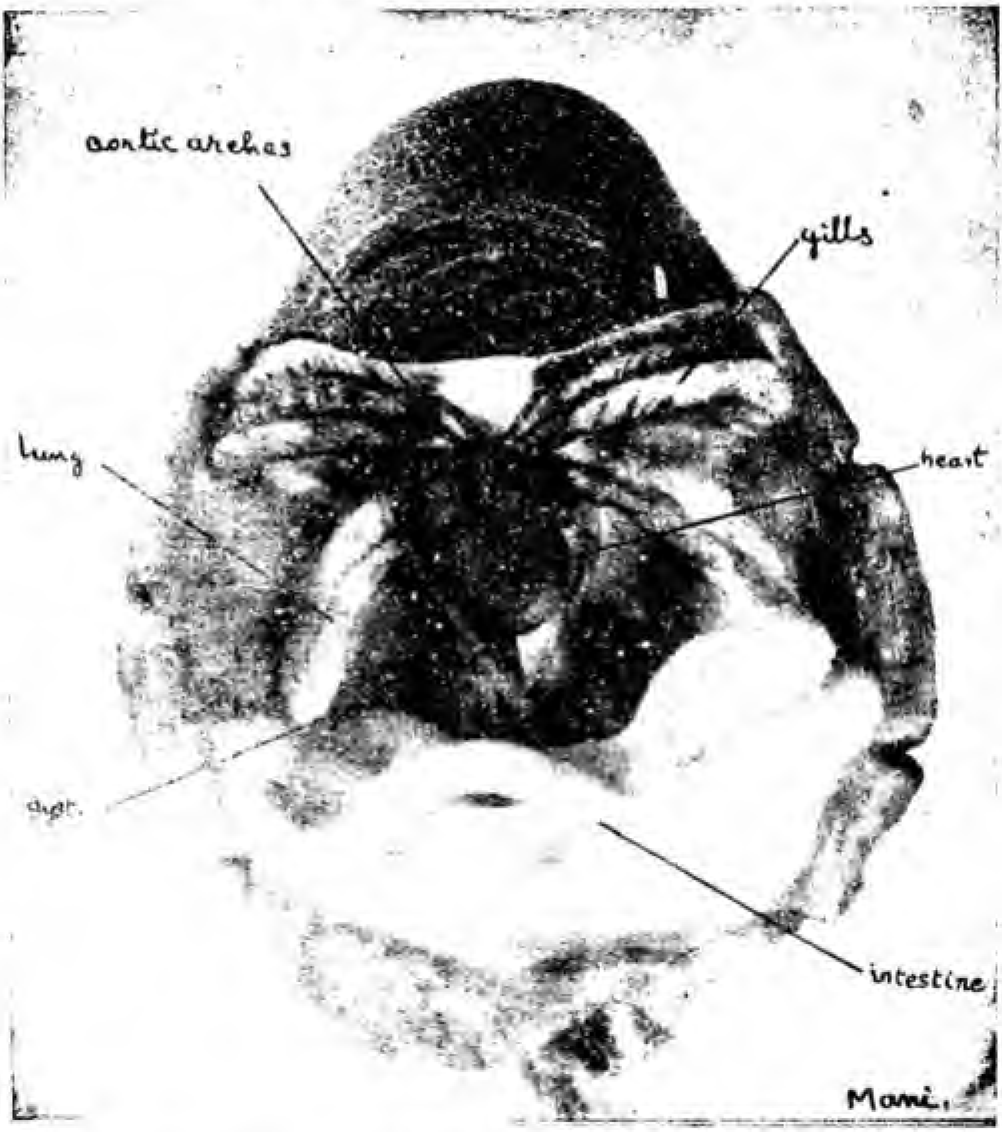


FIG. [illegible] [illegible] stage of the tadpole of frog, with internal gills, lungs and [illegible] photograph of a model in the Zoology Museum, St. John's College, [illegible]

gets twisted once into a spiral. The walls of the looped part fuse and thus give rise to a hollow structure, the heart, which then becomes further subdivided into right and left auricles by a septum growing backwards. Two

large veins, the ***vitelline veins,*** bring the blood from the yolk to the heart and a ***ductus cuvieri*** conveys the blood from the dorsolateral regions of the body of the tadpole. These veins unite together into the sinus venosus. Two ***anterior cardinal*** and ***posterior cardinal veins*** open into the ductus cuvieri. The heart gives off a ***cardiac aorta*** or ***conus arteriosus*** in front. The conus divides into a right and a left branch. Each branch subdivides into three ***afferent branchial vessels*** going to the three external gills. The blood passes through the capillaries in the external gills and returns after oxygenation by three pairs of ***efferent branchial vessels.*** When the external gills disappear and are replaced by internal gills, the afferent branchial vessels reach them and efferent vessels return from them. The circulatory system of the tadpole is now

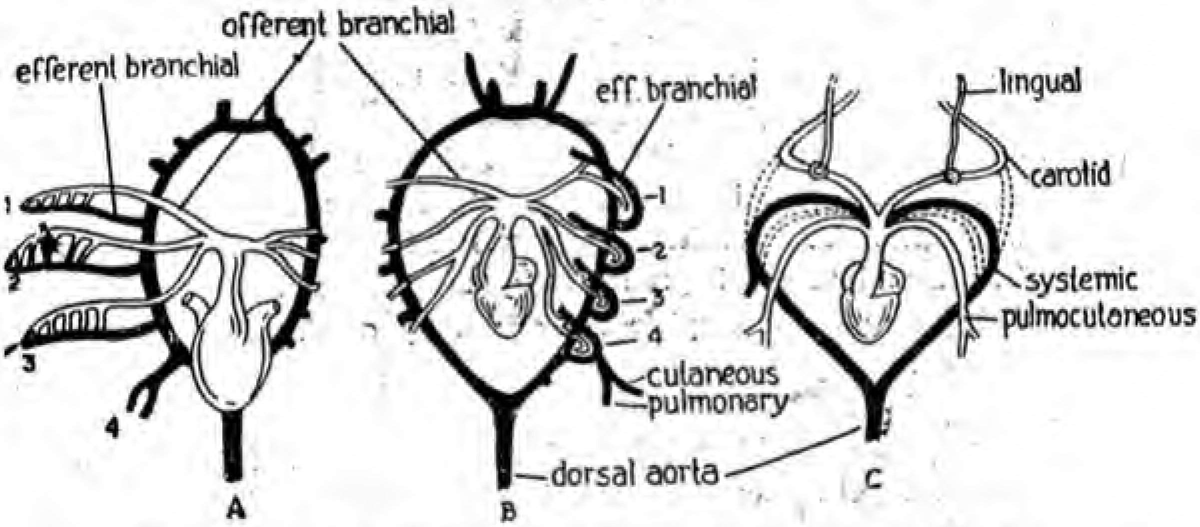


FIG 117 Diagram of the changes in the circulatory system during metamorphosis of frog. The heart and aortic arches in A. of young tadpole with three external gills, B. of the tadpole with internal gills and lungs, and C. of the adult frog derived from B. The dotted lines indicate the vessels that have disappeared.

exactly like that of a fish. With the lungs becoming functional, the blood is supplied to them from branches of the fourth pair of afferent branchial vessels. This contains blood already oxygenated in the gills. The blood returns from the lungs by the pulmonary veins. Now less and less blood flows to the gills and more and more to the lungs. When finally the gills completely shrivel up, the blood goes entirely to the lungs for oxygenation. The afferent branchials now become the three ***aortic arches.*** The first aortic arch becomes the carotid arch, the second the systemic and the third the pulmocutaneous artery of the adult frog.

CHANGES IN HABIT.—The tadpole is at first a relatively sluggish creature ering to aquatic vegetation by suckers. Soon it becomes an actively

free-swimming fish-like form, feeding on soft water plants, breathing by external gills and moving about by the lashing movements of its long tail. Later, its respiration is both branchial and pulmonary. Finally it leaves the water off and on, breathing wholly by its lungs and skin. It gives up vegetarianism and starts feeding on small flies.

SYNOPSIS OF DEVELOPMENT OF FROG

Embryonic

SEGMENTATION. First two cleavages meridional but at right angles to each other. Third cleavage latitudinal and micromeres and macromeres form.

BLASTULA. At the end of segmentation a hollow one-layered vesicle, the blastula results. It encloses the blastocoele.

GASTRULA. Invagination and epiboly lead to a double-layered gastrula. The new cavity is archenteron. The two layers are epiblast or ectoderm and hypoblast or endoderm.

TRIPLOBLASTIC STAGE. Endoderm splits above except in the middle. This middle part becomes notochord, the lateral parts become mesoderm. The ectoderm invaginates and forms the neural tube. The neural tube enlarges anteriorly into the brain. Stomodaeum and proctodaeum complete the alimentary canal. Other organs develop.

Postembryonic

First tadpole larva with sucker attaches to water weeds. Has two pairs of external gills. Becomes an active swimming tadpole with three pairs of external gills. Operculum develops and covers gill slits and external gills are replaced by internal gills. Lungs become functional and the tadpole breathes for a time both by gills and lungs, exactly like the lung-fish dipnoan. Internal gills disappear. Legs elongate, tail shortens and metamorphosis is completed.

RESUMÉ

1. Reproduction in the frog is by the sexual method. The frog breeds only in water.

2. It begins its development as a single cell, the ovum, which is fertilized by the sperm in water, outside the body of the mother.

3. The fertilized ovum is the zygote. It commences development by dividing into a number of blastomeres, that re-arrange themselves to form a hollow blastula.

4. Invagination and epiboly convert the blastula into a gastrula, in which the archenteron is surrounded by the endoderm and the ectoderm forms the outer layer.

5. The mesoderm and notochord appear between these two layers. The ectoderm forms the nerve tube. These three germinal layers give rise to all the organs of the future frog. The embryo elongates into the fish-like tadpole larva that hatches at the end of the embryonic development.

6. The tadpole has external gills, suckers and an elongate compressed tail that serves as the locomotor apparatus. The alimentary canal is coiled like a watch-spring. The tadpole feeds on aquatic vegetation.

7. Internal gills soon replace the external and the lungs gradually become functional. For a time the tadpole breathes by the internal gills, exactly like the Dipnoan or the lungfish.

8. The tadpole completes its development when the gills and the tail disappear and the limbs grow.

Good. Frog never speaks
ill of any body.

CHAPTER VI

PROTOZOA

Protozoa. The PROTOZOA (*protos*=first and *zoon*=animal) are unicellular animals with relatively simple organization. They are mostly microscopic in size. Some are hardly three micra long. A few like *Porospora gigantea* measure fully 16 mm. and are thus visible to the naked eye.

Over thirty thousand species of Protozoa are known from the world. Each species lives in a particular habitat : moist soil, decaying organic matter, fresh-water, salt water or sea water. Many lead a free life. Some live in colonies and a few live fixed to the ground like plants. Numerous others are parasitic in other animals, in which they cause various diseases like malaria, sleeping-sickness, dysentery, etc.

Although it is a general fashion to call them the simplest of all animals, they manage to carry on all the complex activities of life within the limits of a single cell that their body comprises. They cannot therefore be so simple as is usually imagined. Many have complex ***organelles*** or "cell organs" like mouth, whips, cilia and so on. They have often complicated locomotory apparatus. Not all of them are naked protoplasm. A number of them secrete a shell in which they live (Fig. 119). Some build a shell of sand particles. *Globigerina* is a marine protozoan, which produces a new calcareous shell when the old one becomes small (Fig., 119). They occur in such enormous numbers in the sea that when they die, their shells are deposited as globigerina ooze. In course of time the ooze hardens into chalk, such as that of the cliffs of Dover in England. The limestone used in the famous Egyptian pyramids was made by Protozoa, which lived thousands of million years ago. Similarly, Radiolarians are another Protozoa which form flint rocks. *Noctiluca* is a phosphorescent marine protozoan, which lights up the surface of the sea for many square miles. There is a protozoan which lives in a sort of friendly relationship in the gut of the white ant and helps it in digesting the cellulose of the wood for it. One or two possess chlorophyll and are capable, like the green plants, of utilizing the sunlight in synthesizing carbohydrates from the elements of water and carbon dioxide.

Characters.—The Protozoa are recognized by the following characters :

1. Minute, usually unicellular or colonies of a few cells, similar in size, structure and function.

2. Cells spherical, oval or variable, sometimes with protective tests or cases. Not differentiated into tissues.

3. Nucleus single or multiple.

4. Organelles but no organs or tissues.

5. The single cell performs all the funtions of life from locomotion to reproduction.

6. Locomotion by pseudopodial streaming, flagella or by ciliary movements.

7. Mode of nutrition holozoic, holophytic, saprophytic or combination of two methods. Ingestion of food by engulfing or by the action of cilia. Digestion within the food vacuoles.

8. Reproduction asexual by binary or multiple fission and budding or sexual by fusion of gametes.

9. Free-living, commensals, symbionts or parasites.)

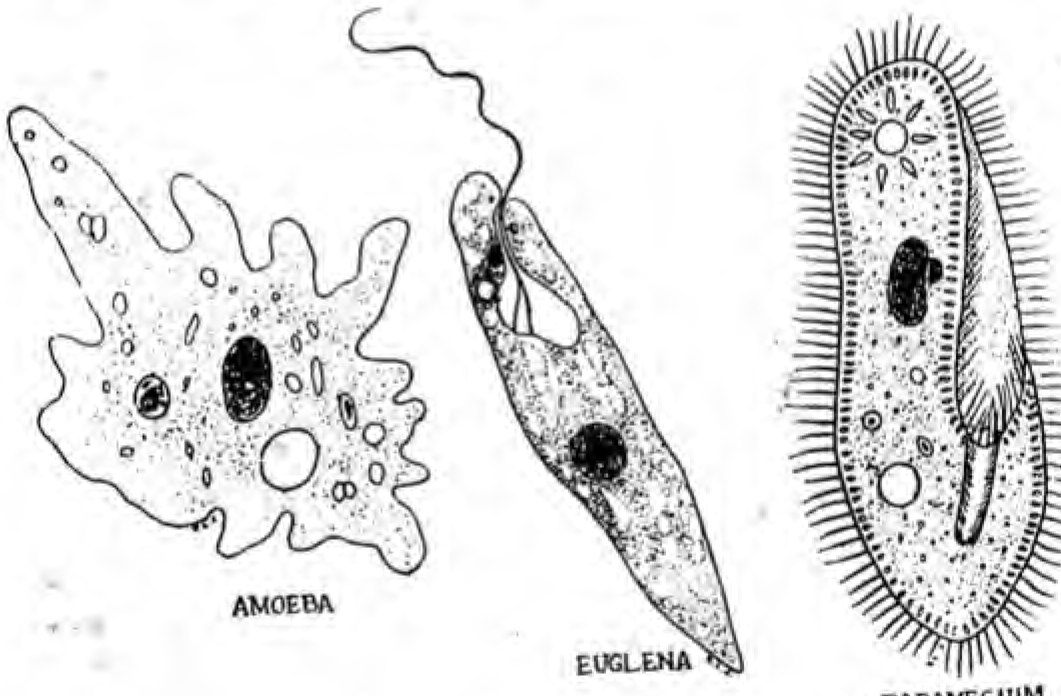


Fig. 118. Phylum Protozoa. Classes Sarcodina, Mastigophora, Ciliata.

Classification.—The phylum Protozoa (Figs. 118, 119, 123) is classified as follows :

Phylum PROTOZOA

Subphylum I. *PLASMODROMA*. Locomotion by streaming or by whip-like threads.

Class 1. **Sarcodina** (= Rhizopoda). Locomotion by pseudopodia. Example : *Amoeba*.

Class 2. **Mastigophora** (= Flagellata). Locomotion by means of flagellum or a whip-like thread. Examples : *Euglena, Trypanosoma, Noctiluca*.

Class 3. **Sporozoa**. Exclusively parasitic, without locomotion when adult. Examples : The Malarial parasites.

Subphylum II. *CILIOPHORA*. Locomotion by cilia.

Class 4. **Ciliata** (=Infusoria). Cilia permanent. Examples : *Paramecium*, *Vorticella*, *Stentor*.

Class 5. **Suctoria**. Cilia in early life. Example : *Sphaerophrya*.

SARCODINA

The SARCODINA are simple Protozoa without permanent organelles of locomotion. They move by pseudopodial streaming.

Classification.

Class SARCODINA

Subclass 1. ACTINOPODA

Order 1. **Heliozoa**. Example : *Actinosphaerium* sun-animalcule.

Order 2. **Radiolaria**. Examples : *Petalospyris* and *Eucyrtidium*.

Subclass 2. RHIZOPODA

Order 1. **Lobosa**. Example : *Amoeba*.

Order 2. **Foraminifera**. Examples : *Globigerina* and *Nummulites*.

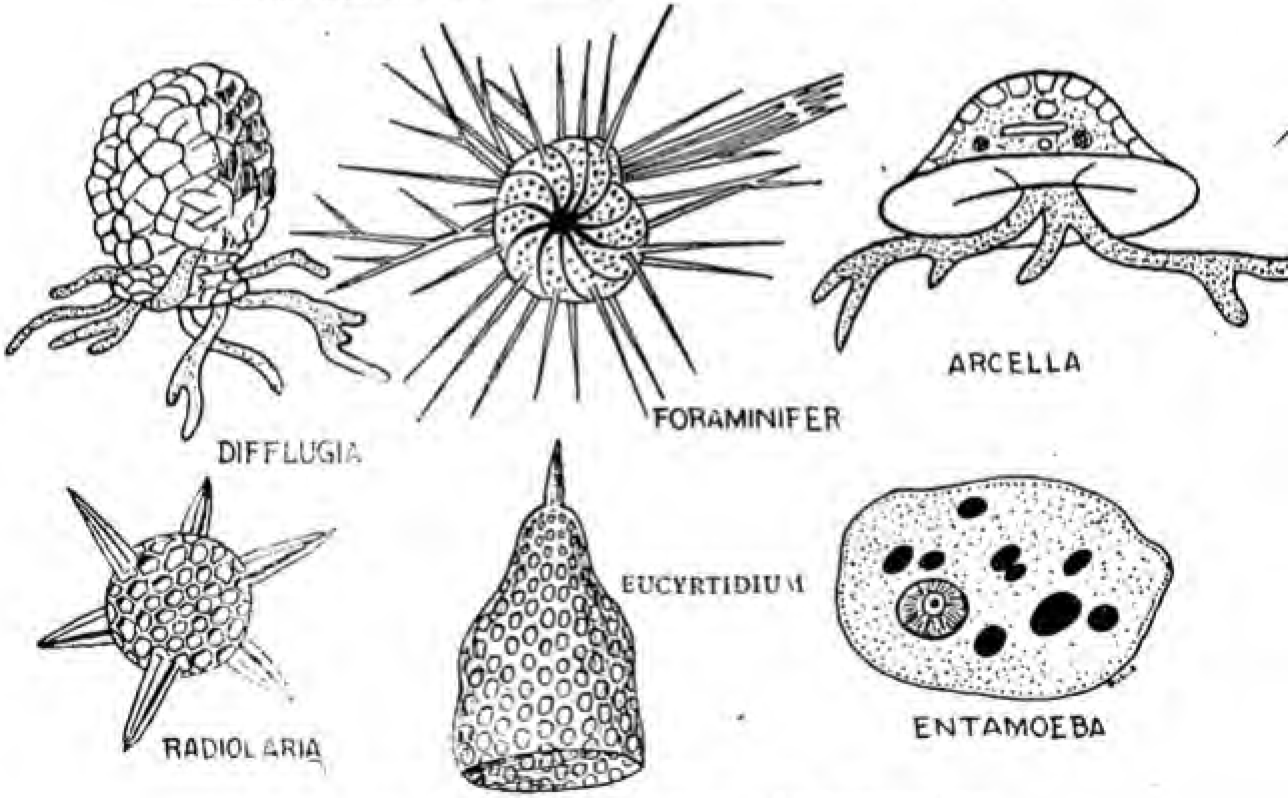


Fig. 119. Phylum Protozoa. Class Sarcodina.

1. AMOEBA

Occurrence and systematic position.—*Amoeba* lives in fresh-water that contains green plants or in brakish water. Fresh-water amoebae occur in a variety of localities, for example, in pools, streams, water troughs and so on. They mostly creep on submerged plants. Some like *Amoeba*

terricola live in moist earth. Many species habitually occur within the bodies of various animals including man. Some of these are harmless to man, as for example, *Entamoeba gingivalis* found in the mouth. Others cause fatal diseases, as for example, *Entamoeba histolytica*, which causes the amoebic dysentery. Amoebae are mostly minute forms, but some like the *Pelomyxa palustris* are giants and measure up to 100 mm. The common species is *Amoeba proteus*, which occurs in clean fresh-water containing green vegetation. Its systematic position is as below:

Phylum PROTOZA
Suphylum *PLASMODROMA*
Class SARCODINA
Order *Lobosa*. With blunt pseudopodia which do not fuse with each other.
Genus *Amoeba*
Species *proteus*.

Structure.—*Amoeba proteus* is hardly a quarter of a millimetre in size. It is colourless and transparent and has a jelly-like appearance (Fig. 120). It has no constant shape but is always changing its outline by flowing, now in one direction and then in another. It has therefore been described as a shapeless mass of protoplasm. The animalcule has no anterior or posterior end and no dorsal or ventral surface.

Amoeba has no cell-wall but the protoplasm is not naked. There is an extremely delicate outer elastic membrane, the ***plasmolemma***. The plasmolemma retains the protoplasm within the cell. Immediately beneath, there is a clear non-granular ***ectoplasm***. Within this is the bulk of the granular ***endoplasm***. The endoplasm is differentiated into an outer stiffer ***plasmogel*** and a deeper more fluid ***plasmosol*** showing streaming movements.

The endoplasm encloses a disc-like ***nucleus***, which can only be seen when the amoeba is killed and stained with certain dyes. There are also several spherical structures called ***vacuoles***. The vacuoles are of two types: ***contractile vacuoles*** and ***food vacuoles***. Often one or more contractile vacuoles occur. They are spherical liquid-filled spaces, which gradually grow larger until a maximum size is reached, when they suddenly collapse and discharge their contents to the outside and thus disappear. They then reform to contract again. There are numerous food vacuoles, in which particles of food enclosed in a watery liquid undergo digestion and absorption. There may be in addition crystals, fat globules and other granules of various sizes scattered in the endoplasm.

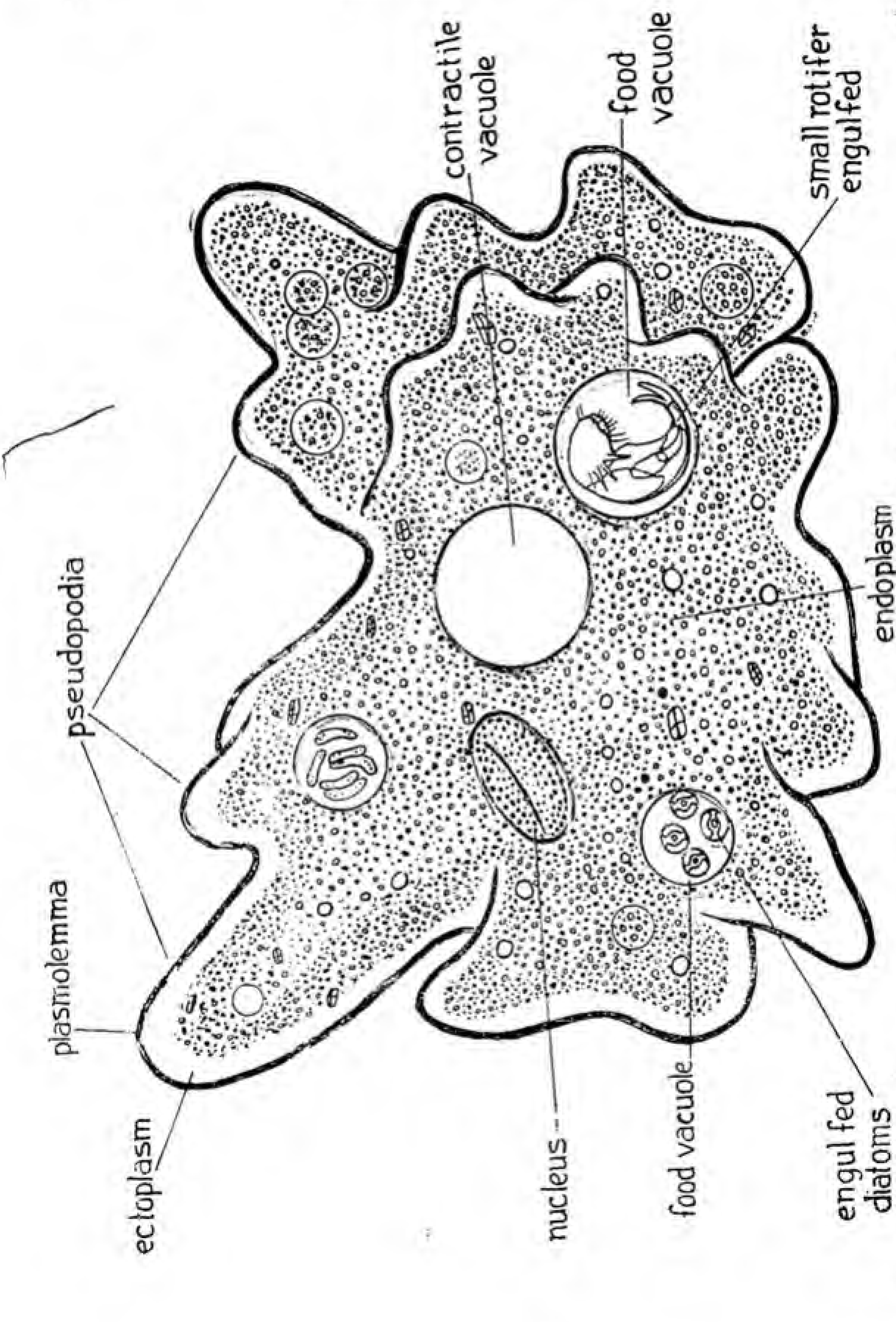


FIG. 120. *Amœba proteus* showing the details of structure.

Motion and locomotion.—A living amoeba is a restless creature. It is always slowly moving and changing shape. Like the leucocytes of the blood, the amoeba is constantly throwing out blunt temporary pseudopodia. The animalcule simply flows in the direction in which the pseudopodium is extending. A pseudopodium continues to advance for some time, but soon stops and another is forming already elsewhere and the amoeba has changed its direction of movement. The progress of the amoeba is thus irregular and apparently aimless. This type of movement is so characteristic of the amoeba that it is called ***amoeboid movement.*** The amoeboid movement is necessarily slow and does not continue long in any one direction.

(**Nutrition.**—The food of amoeba consists of minute aquatic plants and animals. It feeds on bacteria, diatoms and other Protozoa. Amoeba has a "taste" for algae, rotifers (a multicellular worm), small flagellates and *Paramecium.*

Amoeba exhibits a choice in selecting its food. It avoids unwanted particles. It also leaves extremely active animals severely alone.

The food is taken at any spot of the cell-body. When it comes across a food particle, the amoeba (Fig. 122) simply flows around and above it by extending the pseudopodia. The prey is thus ***engulfed*** by the flowing amoeba. The mode of engulfing varies somewhat with the kind of food. If the prey is moderately active, the pseudopodia are thrown out wide, without touching and irritating the prey until it is fully engulfed. If however the food is a meek prey, as for example an alga, the aoemba embraces it tightly with the pseudopodia right at once. The food particles are always engulfed with some quantity of water and thus a food vacuole is formed. The food vacuole gradually moves about in the endoplasm. The prey is killed by an acidic secretion. Later, the food vacuole becomes alkaline to enable the enzymes to digest the food. The digested material is absorbed directly into the protoplasm and the amoeba simply moves away, leaving behind the undigested particles.)

Respiration and excretion.—The water in which the amoeba lives contains dissolved oxygen. The plasmolemma membrane permits the diffusion of this oxygen inward into the protoplasm and the diffusion of carbon dioxide into the water outward. Respiration takes place throughout the surface of the animal.

The contractile vocuole is believed to have an excretory function. Its main function is to regulate the water-content of the cell body. It has been picturesquely described by BUCHSBAUM as "a pump in a leaking ship, in which the pump must be kept going all of the time to keep pace with

the incoming water". Amoeba lives in water and the water constantly leaks into the protoplasm by diffusion through the plasmolemma. It is also taken in with food. Water is also a waste product of metabolism. But for the contractile vacuoles, which expel the excess water periodically, the amoeba is in constant danger of getting diluted.

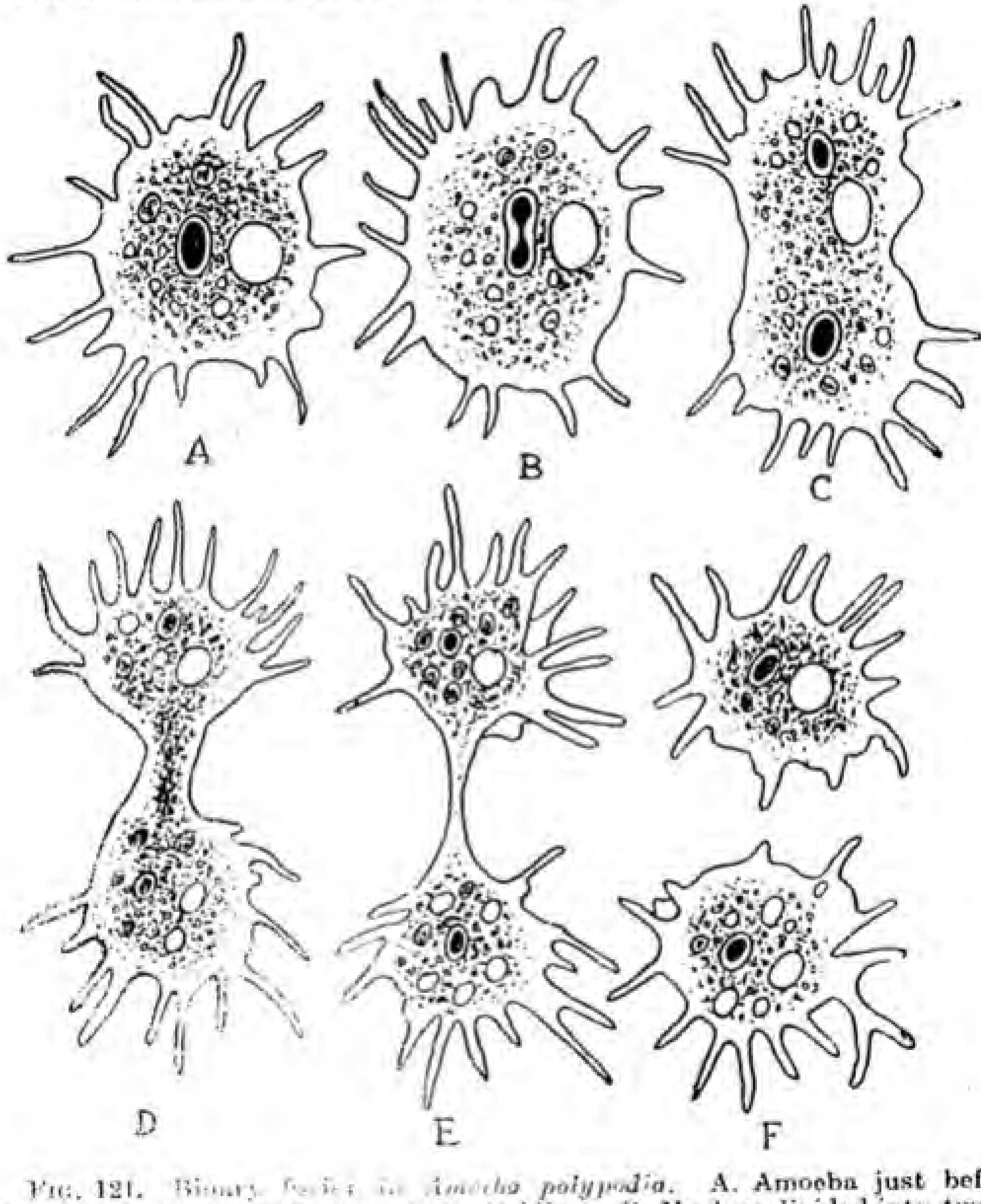


FIG. 121. Binary fission in *Amoeba polypodia*. A. Amoeba just before the beginning of fission. B. Nucleus starts dividing. C. Nucleus divided into two. D-E. The cell body divides into two. F. Two new daughter amoebae. (*Modified from Doflein's "Lehrbuch der Protozoenkunde" after F.D. Schulze*).

Reproduction.—When food is plentiful and other conditions are favourable, the amoeba grows rapidly in size. It then reproduces by undergoing ***binary fission*** (Fig. 121) or dividing into two by mitosis. Amoeba reproduces once in every few days and each division requires only about an hour. When conditions are unfavourable and the water in which

the amoeba lives is drying up, it undergoes ***multiple fission*** (Fig. 122) and ***sporulation***.

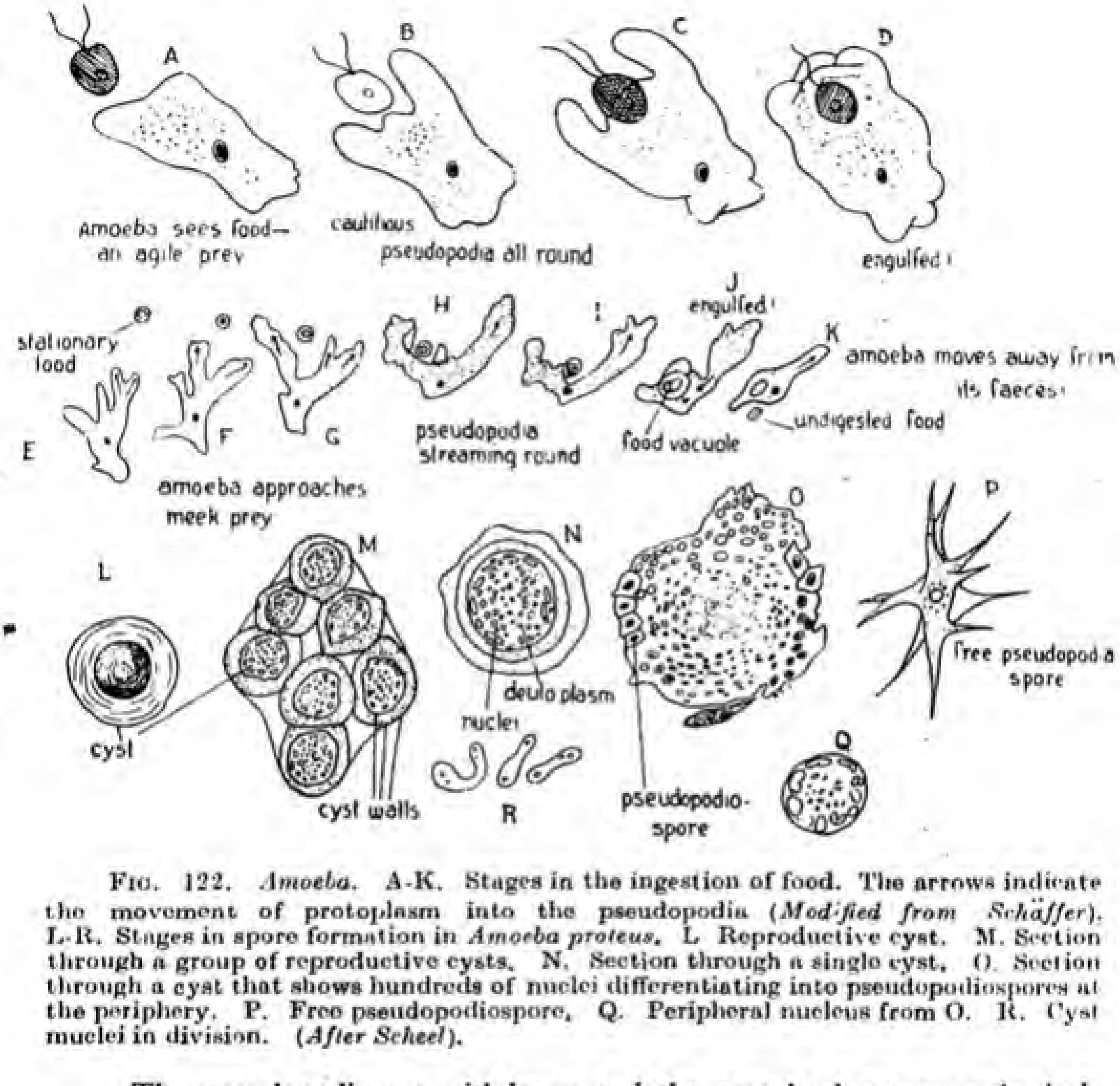


FIG. 122. *Amoeba*. A-K. Stages in the ingestion of food. The arrows indicate the movement of protoplasm into the pseudopodia (*Modified from Schäffer*). L-R. Stages in spore formation in *Amoeba proteus*. L. Reproductive cyst. M. Section through a group of reproductive cysts. N. Section through a single cyst. O. Section through a cyst that shows hundreds of nuclei differentiating into pseudopodiospores at the periphery. P. Free pseudopodiospore. Q. Peripheral nucleus from O. R. Cyst nuclei in division. (*After Scheel*).

The pseudopodia are withdrawn and the amoeba becomes spherical. Distinction between ectoplasm and endoplasm ceases. After a time the amoeba starts rotating slowly but without locomotion. Three thick layers or ***cyst walls*** develop externally. The nucleus divides amitotically into about five hundred bits. Each nuclear bit is now covered by a nuclear membrane and becomes surrounded by cytoplasm. These are the ***pseudopodiospores*** and are the resting stages of the amoeba. In this encysted condition the pseudopodiospores can withstand prolonged and complete desiccation. The cysts are blown by wind and dispersed far and wide. When again the cysts become wetted by water, the cyst wall bursts

and the pseudopodiospores escape. Each one of them grows up in due time into an adult amoeba.

Although amoeba has no sex, it reproduces its kind by sexless methods of division and spore formation. The reproduction in amoeba is thus ***asexual,*** in contrast to sexual method of the frog.

Behaviour.—Amoeba has no complex organs of special sense. It can still respond to various kinds of stimuli. It can, for example, distinguish food from particles that are not useful. The responses of the amoeba to the various changes in its environment constitute the ***behaviour*** of the animal.

When hungry, amoeba seeks food. Contact with food draws out the pseudopodial processes. Amoeba avoids very strong lights. When it is creeping slowly away from a strong ray of light, if it comes repeatedly against strong light, it soon changes its direction of movement. Temperature changes affect the amoeba very markedly. Both near freezing point and at temperatures above 30°C its activities come to a standstill. If an amoeba is poked with a fine-pointed needle, it reverses its direction and moves away. If the poking is repeated vigorously, it contracts into a ball-like mass and feigns death by remaining motionless for some time.

The behaviour of the amoeba emphasizes what can be achieved even in the absence of complicated tissues and organs. It shows that protoplasm can very well carry on all the varied vital activities like ingestion, digestion, egestion, respiration, excretion, response to stimuli, etc. Amoeba exhibits ***avoiding reaction*** against obstacles such as the needle-prick and other unfavourable environments like strong light. After a number of repeated attempts, it can find the best kind of existence. It is able to learn by *trial-and-error-method*. Amoeba is thus ***adaptive,*** in other words, it can modify its behaviour by experience. All these characters are exactly the same as in man. The life processes of an amoeba are not in any way essentially different from those of man. The only difference is one of degree and not of quality.

SYNOPSIS

1. Amoeba is a protozoan without a shell and without permanent organelles of locomotion and feeding.

2. Pseudopodia not only bring about locomotion but also engulf food particles.

3. Respiration takes place on the entire surface of the cell body. The contractile vacuoles eject the excess of water.

4. Reproduction is by binary fission when conditions are favourable and by multiple fission with spore-formation when unfavourable.

5. Amoeba is capable of response to stimuli like all other animals and it is adaptive in exactly the same way.

Other Important Sarcodina

A number of harmless and pathogenic *Amoebae* live in the intestine of man. *Entamoeba coli*, for example, is a harmless species which lives as a ***commensal*** in the upper portion of the large intestine, where the faeces is yet pulpy. The life-history includes an asexual multiplication and a spore-formation, leading to cysts with 8 nuclei. Healthy individuals become infested by accidental ingesting of the cysts.

Entamoeba histolytica inhabits the small intestine of man in whom it causes enteritis or amoebic dysentery. It ingests epithelial cells, bacteria, leucocytes and erythrocytes. In addition to dysentery, it also gives rise to abscesses of liver, lungs and occasionally of brain also. It forms cysts differing from those of *E. coli* in having only four nuclei.

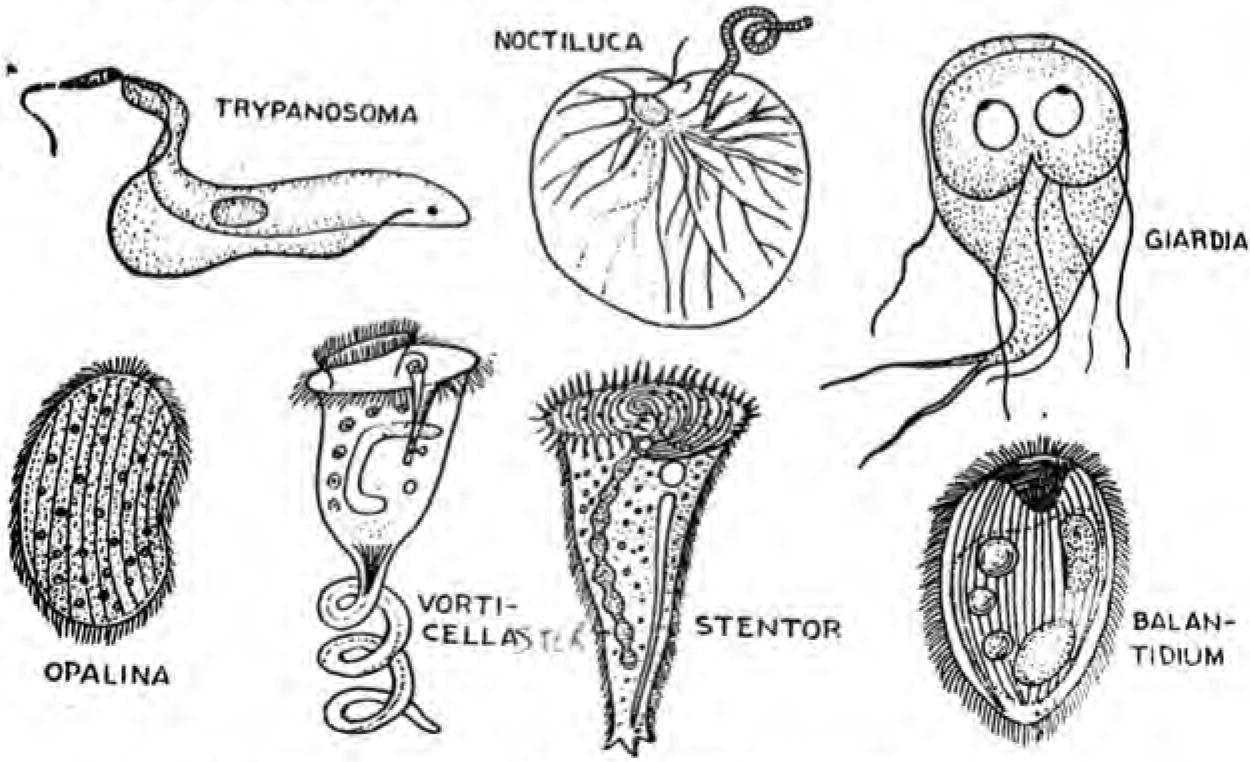


Fig. 123. Phylum Protozoa. Classes Mastigophora and Ciliata.

MASTIGOPHORA

The Mastigophora (*mastig*=whip, *phoros*=bearing), also commonly called Flagellata, are a remarkable group of Protozoa (Fig. 123). They have

one or more whip-like threads, which are used as locomotor organelles. Many of them contain chlorophyll and synthesize carbohydrates like green plants. They are mostly free-living but some like *Proterospongia* and *Volvox* form colonies. Some like the phosphorescent *Noctiluca* are purely marine. A number of Mastigophora are pathogenic parasites of man. *Trypanosoma gambiense* causes the dreaded "sleeping sickness" in Africa. *Leishmania donovani* causes Kala-azar and *L. tropica* the oriental sore in India.

The Mastigophora differ from the Sarcodina in the presence of the flagellum or the whip-like thread.

Classification.

Class MASTIGOPHORA

- Subclass I. PHYTOMASTIGINA. Plant-like flagellates.
  - Order 1. **Dinoflagellata.** Example : *Noctiluca.*
  - Order 2. **Euglenoidina.** Example : *Euglena.*
  - Order 3. **Phytomonadina.** Example : *Volvox.*
- Subclass II. ZOOMASTIGINA. Animal-like flagellates.
  - Order 1. **Protomonadina.** Example : *Trypanosoma*
  - Order 2 **Polymastigina.** Example : *Giardia.*

2. EUGLENA

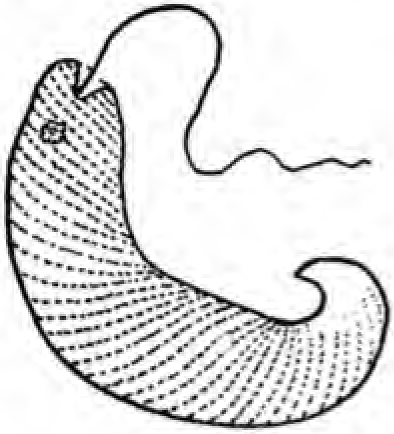
Occurrence and Systematic position.—*Euglena* is one of the most common Mastigophora found in fresh-water. It often occurs in such large numbers that a green scum appears on the surface of water. There are many species but *Euglena viridis* and *E. gracilis* are cosmopolitan forms. They occur in a variety of situations, for example, in ponds, tanks, stagnant water basins and flower vases. The systematic position of *Euglena* is as follows :

Phylum PROTOZOA
Subphylum *PLASMODROMA*
Class MASTIGOPHORA
Order *Euglenaceae*
Genus *Euglena*
Species *viridis.*

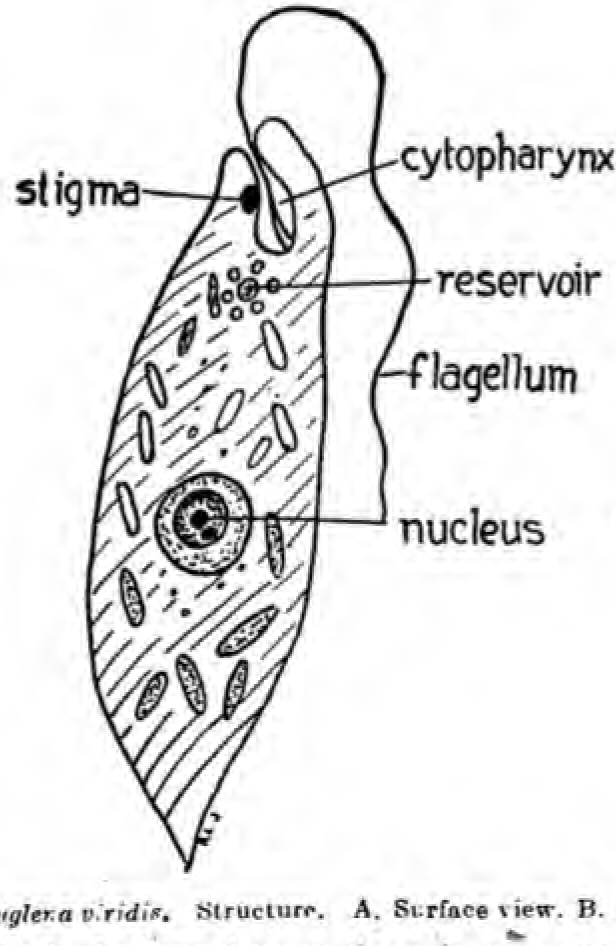
Structure—*Euglena* (Fig. 124) differs sharply from amoeba in having a constant shape. It has also an anterior and a posterior end. Its cell body is elongate, with the anterior end broadly truncated and posterior end pointed. The constant shape of the euglena is due to the presence of a thin flexible cell wall or ***pellicle.*** The pellicle is marked by parallel striations running obliquely across the cell body. Within the pellicle is a thin ectoplasm surrounding a granular endoplasm.

At the anterior end there is a funnel-shaped depression the ***cytostome*** or "cell mouth." The cytostome leads into a short ***cytopharynx*** or

"cell gullet". From the cytopharynx there emerges a long thread-like transparent ***flagellum***. The flagellum consists of a contractile axial filament surrounded by a delicate sheath. It arises from a granular ***blepharoplast*** in the ectoplasm



A



B

FIG. 124. *Euglena viridis*. Structure. A. Surface view. B. Internal structure.

Just behind the cytopharynx there is a permanent large globose ***reservoir***. Close by is located a vacuole into which several smaller

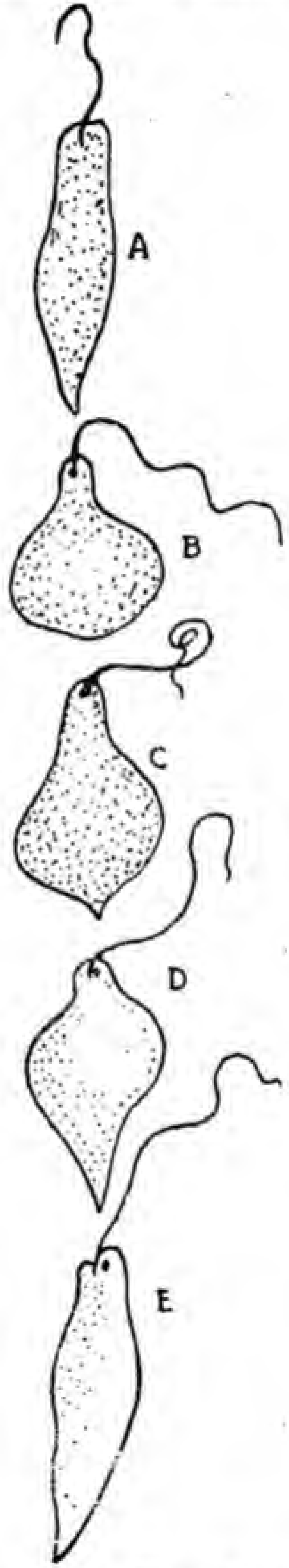


FIG. 125. Locomotion in Euglena. Worm-like contractions and expansions of the cell body, aided by the flagellum produce the characteristic "euglenoid" movements.

contractile vacuoles empty their contents. The reservoir ejects its contents through the cytopharynx at intervals. On one side of the reservoir is the eye-spot or ***stigma*** that is sensitive to light. A spheiical nucleus lies near the anterior end in the middle.

The green colour of the euglena is due to the presence of a number of circular discs, the ***chromatophores***. The chromatophores contain chlorophyll Among the other cytoplasmic inclusions are granules of the carbohydrate ***paramylum*** allied to starch and ***pyrenoids***, which are proteids.

Locomotion.—Euglena moves in different ways : it can swim, creep, squirm or roll. The flagellum is the organelle of locomotion It beats back and forth and draws the body of the euglena through the water in a spiral rotation. The result is that the animal progresses in a straight line, while the cell body is itself twirling.

When moving on a solid substratum, euglena squirms in a characteristic manner described as ***eugelnoid movement*** (Fig. 125). The cell wall is elastic and permits considerable change of shape. The euglena swells up at the posterior end, then in the middle and finally in front. These contractions resemble the peristaltic contractions of the alimentary canal of frog. The squirming is combined with slow sinuous movements resulting in a forward progression.

Nutrition.—The nutrition of euglena is largely holophytic. The eulgena synthesizes carbohydrates from the elements of water and carbon dioxide with the help of chlorophyll of the chromatophores in the presence of sunlight. The product of this photosynthesis is a carbohydrate called ***paramylum***, which is allied to the starch synthesized by the green plants.

Euglena varies its diet by ***saprophytic*** nutrition. The decaying organic matter dissolved in the water is absorbed by the animalcule. Euglena can thus exist even in the absence of sunlight.

Respiration and excretion.—Respiration takes place by the entire surface of the cell body. The carbon dioxide produced in respiration is undoubtedly re-utilized in part within the cellbody in photosynthesis. It is equally probable that the oxygen liberated in the photosynthetic process is also used up for respiration. Excess water and other wastes collect in the contractile vacuoles. These empty the wastes into the reservoir, whence they are expelled through the cytostome.

Reproduction.—Euglena reproduces asexually like amoeba. It undergoes mitotic binary fission along the length of the cell body. The anterior

organelles are duplicated by the growth of new ones. Fission begins in the anterior end and progresses backward. The nucleolus within the nucleus is peculiar in some respects and it is called ***nucleocentrosome***. This elongates and the chromosomes lie parallel to it Then they gather around the middle of the nucleocentrosome and split up longitudinally. Their halves separate and travel to opposite ends.

Under conditions of drought euglena becomes encysted in a thick gelatinous wall, after losing the flagellum. After a period of rest, the encysted euglena undergoes longitudinal fission by mitosis. These daughter euglenae become encysted within the parent cyst and undergo further subdivision. When favourable conditions return, the cyst bursts and the young euglenae escape and develop flagella.

Behaviour.—Euglena reacts to various stimuli in much the same manner as amoeba, but it is attracted by light.

Comparison between amoeba and euglena.– Euglena differs sharply from amoeba in several respects :

	AMOEBA	EUGLENA
1.	Shape not constant	Shape constant
2.	Cell wall absent	Cell wall present
3.	Locomotion by pseudopodia	Locomotion by flagellum, contracting and spiral squirming of cell body
4.	No cytostome, cytopharynx or eye-spot	Cytostome, cytopharynx and eye-spot present
5.	Nucleolus normal	Nucleolus a nucleocentrosome
6.	Food vacuoles present	Food vacuoles absent
7.	Contractile vacuoles empty to the outside anywhere from the cell body	Contractile vacuoles empty into the reservoir, which in its turn empties into cytopharynx and thence to the outside
8.	Chlorophyll absent, nutrition holozoic	Chlorophyll present, nutrition holophytic and saprophytic
9.	Binary fission in any plane	Binary fission always longitudinal

OTHER IMPORTANT MASTIGOPHORA

Giardia (formerly *Lamblia*) *intestinalis* (Fig. 123) is a pear-shaped, bilaterally symmetrical flagellate that occurs in the duodenum and small intestine of man. It possesses anteriorly on one side an oblique depression, functioning as a sucker. There is no cytostome but there are eight flagella. It multiplies and sets up inflammation of the intestine and thus leads to

diarrhoea. The resistant cysts that are voided with the faeces, when accidentally taken in water or raw vegetables, cause infestion.)

Trypanosoma (Fig. 123) possesses a single flagellum that forms an undulating membrane. They are pathogenic parasites in the blood of Vertebrates and in the digestive tracts of insects

Trypanosoma gambiense and *T. rhodesiense* are polymorphic species that occur in human blood and give rise to the dreaded African "sleeping-sickness." They multiply by longitudinal fission, till the blood swarms with the parasites. Then they gradually disappear from the blood, but occur abundantly in the neural canal, spleen, etc. After a period of rest, the parasites re-enter the blood and multiply. The victim becomes weak and anaemic due to the toxic nature of the metabolic wastes of the parasite. The parasites ultimately invade the cerebrospinal fluid that surrounds the brain and fills the ventricles of the brain. The person loses consciousness and sinks gradually into a comatose condition from which he never wakes up. The parasites are transmitted by the blood-sucking *Glossina* or tse-tse-fly. When this fly sucks the blood of infected antelope or man, it takes in a number of the *Trypanosoma* individuals. The parasites undergo further change in the digestive tract of the fly. They continue to multiply and in about 16—20 days, long, slender trypanosomes migrate up the alimentary canal and reach the salivary glands of the fly. Here again they continue to change and multiply and give rise to short stumpy forms. If such an infested fly bites a man, the infective forms are injected into his blood, where they rapidly multiply and in due time cause sleeping-sickness.

Trypanosoma evansi causes the "surra" disease in horse, mules, camels and cattle in India, Burma, Indo-China and the neighbouring countries. Fever, emaciation, oedema, weakness and paralysis lead on to death. The parasite is transmitted by the blood-sucking flies *Tabanus* and *Stomoxys*.

Leishmania donavani causes the notorious ***kala-azar*** of man in India. The victim becomes emaciated, with greatly enlarged spleen. The ***Leishman-Donavan bodies***, as the parasites are commonly called, are found in the cells of the capillaries of liver, spleen, bone marrow, lymph glands, etc. The common bed-bug is suspected to be a vector of the parasite.

Leishmania tropica causes the so-called Delhi-sore or Oriental-sore in India, Persia, Arabia and other places. The sandflies, *Phlebotomus*, are suspected to transmit the parasite

Volvox globator (Fig. 126) is a colonial Flagellate common in most stagnant waters. It is essentially a hollow sphere about half a millimetre in diameter. The wall of the sphere is composed of about ten thousand cells

arranged in a single layer. Each cell has its ***cell envelope***, which the cell contents do not entirely fill up. As the envelope of each cell is pressed by those of other cells all round, the sphere has a hexagonal or honeycomb-like surface. A ***colonial envelope*** of the same material as the cell envelope covers the sphere.

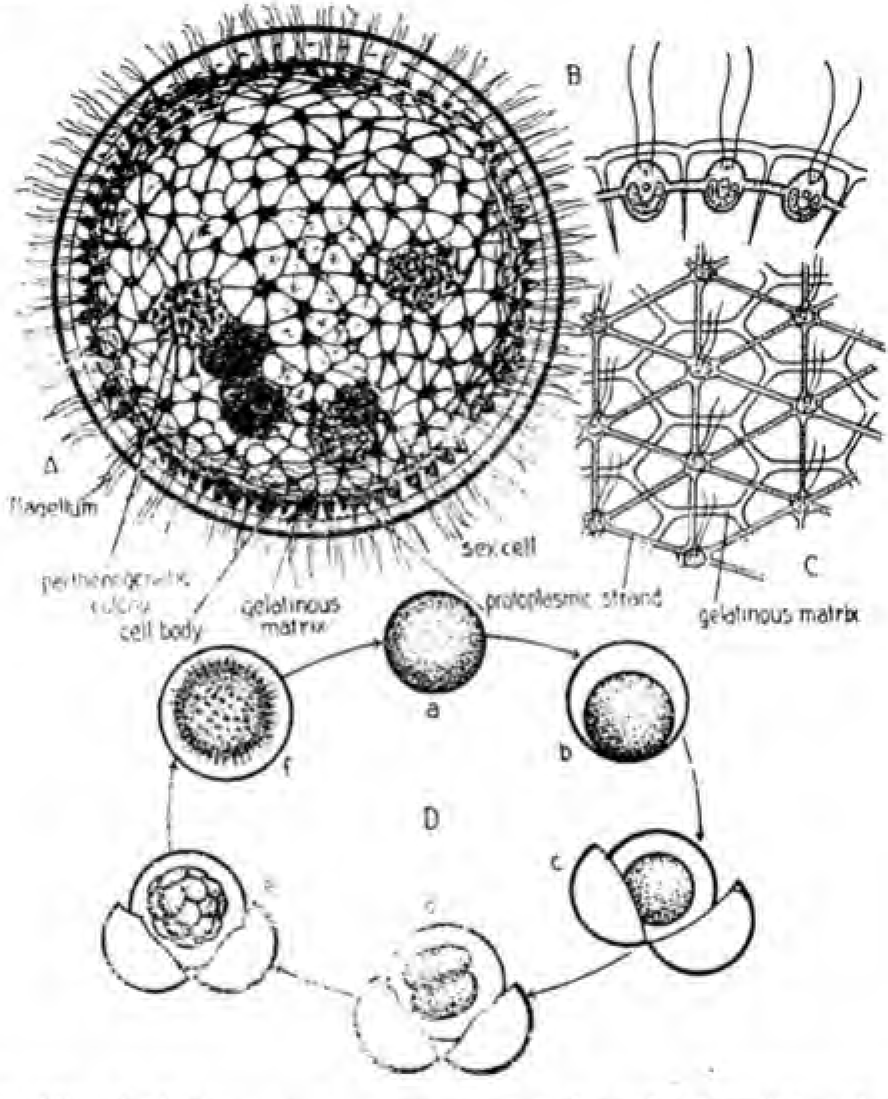


FIG. 126 A. *Volvox* [illegible], a protozoan colony that lives in ponds and swims by the action of flagella, [illegible] by protoplasmic strands (B & C) between neighbouring cells. D. Sexual reproduction and development of *Volvox*; *a*. fertilized zygote, *b*. encysted [illegible] zygote divides into two, *d-e*. successive divisions, *f*. young colony in cyst [illegible] (Arranged from *Kircher and Kolliker*).

The cells that compose the colony are connected together by ***protoplasmic bridges***. Each cell has cytoplasm, nucleus, contractile vacuole, chromatophore, ***amylum body*** and paired flagella on the outer surface. The united movements of the flagella of all the cells bring about locomotion of the entire colony.

These ***somatic cells*** reproduce by binary division and increase the size of the colony. They cannot however produce a new colony.

Eight specialized cells, called ***parthenogonidia***, ensure the production of a new colony. Each parthenogonidium repeatedly divides within its envelope. A miniature spherical colony thus projects into the central cavity of the parent colony. It escapes in due course and grows into an adult colony. After several such asexual colonies, the ***macrogametes*** and ***microgamates*** of the sexual generation appear in the colony. Fertilization of the macrogamete by the microgamete yields the ***zygote***, which in winter encysts within a double-layered envelope. In the spring it repeatedly divides and produces a new colony.

Comparison Between A Protozoan Colony and A Metazoan Animal

A protozoan colony is a multicellular body with physiological differentiation of the cells almost as in the metazoa. There are however no true tissues. The digestion of the food is ***intracellular*** in the colony but ***extracellular*** in the metazoa. Development of the two classes of animals is also essentially different: the body of all the metazoa is formed out of two or more germinal layers. The Protozoan colony lacks these layers. The colonial Protozoa probably mark a step in the transformation of Protozoa into metazoa.

SPOROZOA

The Sporozoa are parasites.—The Sporozoa lead a parasitic life. A ***parasite*** is an organism that lives in or on another, the ***host***, derives all benefit from this association and causes harm to the host. The parasite obtains its food and shelter at the cost of the host. The host can live without the parasite and indeed healthily, but the parasite cannot exist without the host.

Ectoparasites live on the surface of the body of their hosts and ***endoparasites*** live within the body. Many parasites manage to get transferred from one host, which they have improverished or almost killed, to another ***intermediate host***, which transmits the parasite from one ***definitive host*** individual to another. Many of the Sporozoa cause various diseases in their hosts and are therefore ***pathogenic parasites***.

A parasitic mode of life ensures unpaid shelter and food. The parasite has thus not to "work hard for a living". Ready-made food comes to it ; it need not have special food-catching organs. It need not even move; locomotor organs are absent. The Sporozoa are ***obligatory*** parasites, which are incapable of leading a free life. They therefore

lack pseudopodia or flagella. They have no cytostome and no food vacuole. Even a parasite must reproduce. The method of reproduction in the Sporozoa is perhaps the only complicated thing about them.

The Sporozoa live in all sorts of organs of their hosts : some live in the blood, others in the gut, kidneys and various other organs. All are pathogenic parasites.

Classification.

Class SPOROZOA

Subclass I. TELOSPORIDIA

Order 1. **Gregarinida.** Example : *Monocystis* parasitic in earthworm.

Order 2. **Coccidia.** Example : *Eimeria* parasite in the liver of mammals.

Order 3. **Haemosporidia.** Blood parasites. Example: Malarial parasite of man.

Subclass II. NEOSPORIDIA. Parasites in fishes, Arthropoda, etc.

3. THE MALARIAL PARASITES OF MAN

Bionomics.—Malaria is the most deadly of all diseases of man in the world as a whole. Malarial fevers are characterized by the periodicity of the symptoms, deposition of a pigment in the tissue and by the enlargement of the spleen. Other animals besides man, for example, monkeys and birds, also suffer from malaria

In 1880, a French army physician, LEVERAN, discovered that malarial fevers are caused by a sporozoan parasite, which develops in the red corpuscle of man. There are three types of malarial fevers in man : the ***tertian, quartan*** and ***pernicious*** or ***tropical*** malaria. The first two are ***intermittent*** but the tropical malaria is ***continuous*** and irregular. In the tertian ague there is a recurrence of fever every third day and in the quartan every fourth day. The tertian fever is caused by *Plasmodium vivax*, the quartan by *Plasmodium malariae* and the pernicious malaria is caused by *Laverania malariae* (often wrongly called *Plasmodium immaculatum* and *P. falciparum*). The systematic positions of these three species of malarial parasites are as follows :

Phylum PROTOZOA

Subphylum *PLASMODROMA*

Class SPOROZOA

Subclass *Telosporidia*

Order H a e m o s p o r i d i a

Family Plasmodiidae

Genus *Laverania*

Species *malariae.*

Genus *Plasmodium*

Species *vivax* and *malariae*.

Malarial fevers are transmitted from one person to another by the bite of the females of the mosquitoes called *Anopheles*. The female mosquito alone sucks blood and the male is incapable of feeding. The Anopheles punctures the skin and sucks the blood. While doing so it pours into the wound a quantity of saliva to prevent the clotting of the blood. If the person thus bitten by the mosquito is suffering from malaria, the malarial parasites are also sucked up with the blood by the mosquito. The parasites complete their development in the mosquito and reach its salivary glands. When this mosquito bites a healthy person, the parasites are injected into his blood with the mosquito's saliva.

The malarial parasite has thus two hosts: Man is the ***definitive*** or ***main*** host and the mosquito is the ***intermediate*** host. The malarial parasites are as truly parasitic in the mosquito as in man. They cannot complete their full life-history in the absence of either of them. The parasites reproduce asexually in man and sexually in mosquito. There is thus an alternation of asexual and sexual generations and of hosts. Such a mode of reproduction is called ***cyclic heterogenesis***.

Life-cycle In Man

The life-cycle of the malarial parasites in man comprises 1. growth in the red corpuscles. 2. schizogony or multiple fission and attack of healthy corpuscles and 3. formation of gametocytes.

Growth.—When an infected Anopheles bites a healthy person, it injects into his blood the ***sporozoites*** of the malarial parasites with its saliva. The sporozoites are minute eel-shaped cells, which actively wriggle about among the corpuscles. Each sporozoite immediately attacks a red corpuscle and pierces its way into it by the pointed end. When inside the corpuscle, the sporozoite becomes rounded into an amoeba-like ***trophozoite***. It is now safely lodged and is assured of abundant and rich food. It proceeds to feed on the substance of the corpuscle. It throws out pseudopodia and grows steadily in size. A conspicuous vacuole appears near the nucleus. As the trophozoite grows in size, granules of ***melanin***, a brown pigment, appear in its cytoplasm. Ultimately the trophozoite almost fills the red corpuscle, which it has by now destroyed.

Schizogony.—The trophozoite now commences to reproduce asexually by multiple fission within the almost dead red corpuscle. This process of reproduction is known as ***schizogony***, and the trophozoite which is ready for schizogony is a ***schizont***.

The nucleus of the schizont repeatedly divides until about a dozen nuclei are produced. The melanin granules accumulate in the middle. The cytoplasm becomes segmented off round each nucleus and thus a

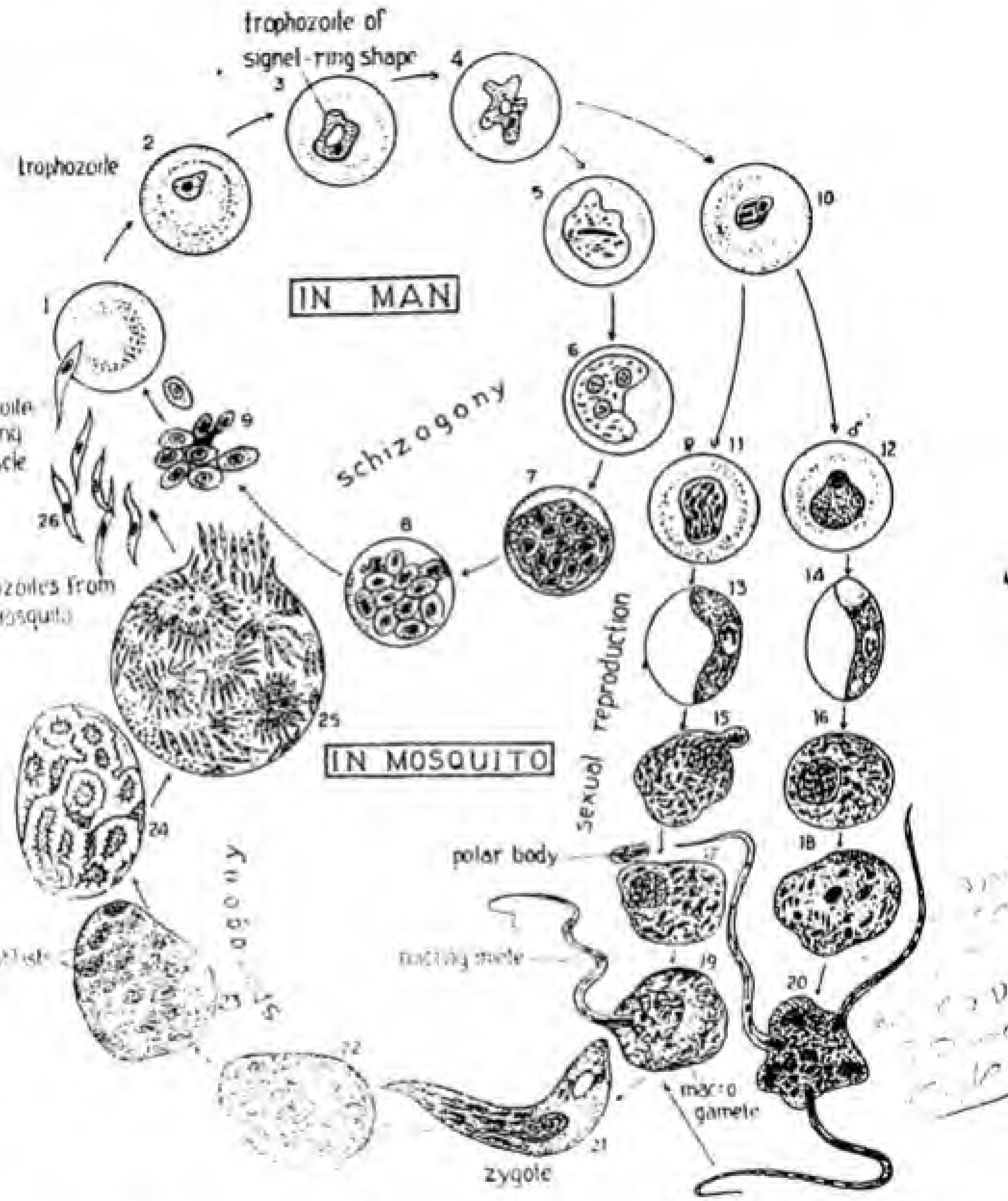


FIG. 127. Life-cycle of *Plasmodium vivax* that causes the tertian malarial fever in man. 1-9. Stages in the asexual reproduction of schizogony in man completed in 48 hours, 10-21. Stages of gametogenesis and sexual reproduction in the wall of the digestive tract of the female *Anopheles* mosquito. 22-26. Asexual reproduction of sporogony in the mosquito (*redrawn from Schaudinn and Grassi*).

number of ***merozoites*** are produced. The red corpuscle now bursts and the merozoites escape into the plasma. They at once attack healthy red corpuscles. One entering these, the merozoites once more become tropho-

zoites, grow at the expense of the red corpuscle and again reproduce by schizogony. This gives rise to another generation of numerous merozoites. In this manner the red corpuscles are destroyed in progressively increasing numbers. The person suffering from malaria thus suffers from anæmia and melanin becomes deposited in spleen, liver, kidneys, and blood capillaries of the brain.

The duration of growth and of schizogony differs in different species. In *Plasmodium vivax* a cycle is completed in forty-eight hours, so that the merozoites escape every third day. This causes the tertian fever. Schizogony in *P. malariae* requires seventy-two hours, so that the merozoites attack fresh corpuscles every fourth day and the quartan fever is caused. In *Laverania malariae* schizogony period is irregular and there are always some merozoites attacking healthy corpuscles, thus causing irregular or continuous fever.

Formation of the gametocytes.— After a certain number of generations of merozoites, schizogony ceases. The trophozoites do not undergo multiple fission, but give rise to larger ***macrogametocytes*** and smaller ***microgametocytes***, which are the sexual reproductive bodies. No further development is possible in the human blood. The gametocytes occur in large numbers in the blood and if no Anopheles sucks them up with the blood, they are all destined to perish. The anopheles mosquito comes to their aid in their hour of danger.

LIFE-CYCLE IN THE MOSQUITO

The life-cycle of malarial parasites in the mosquito includes 1. the sexual reproduction and formation of ookinete and 2. spore formation or sporogony.

Sexual reproduction.— If an anopheles bites a malarial patient, it sucks with his blood all stages of the malarial parasites. The trophozoites and merozoites die in the alimentary canal of the mosquito but not the gametocytes.

The gametocytes are actually stimulated to further development by the digestive fluids of the alimentary canal of the mosquito. The macrogametocyte escapes from the red blood corpuscle. Its nucleus divides into two unequal portions. The smaller is thrown off as a polar body and the other gathers the cytoplasm around itself and thus becomes a ***macrogamete*** ready for fertilization. male gamete

The microgametocyte becomes rounded and ejects the melanin granules. A number of slender, clear, thread-like processes of the cytoplasm form on the surface. These lash about vigorously. The nucleus has by

gamete

this time divided into eight ***karyosomes***. Each karyosome enters one of the lashing threads, which now wriggles away as the ***microgamete***.

The macrogametes and microgametes fuse with each other and form ***zygotes***. The zygote then becomes elongated like an euglena and is called ***ookinete***. The ookinete bores its way to the surface of the gut and becomes encysted on the wall of the alimentary canal of the mosquito.

Sporogony.—The ***oocytes*** or the encysted ookinete absorb nourishment from the tissues of the mosquito. The mosquito thus becomes diseased and swellings develop on the surface of the gut.

The oocyte nucleus divides repeatedly and each nuclear bit becomes surrounded by cytoplasm. Thus numerous ***sporoblasts*** are formed.

The nucleus of the sporoblasts again divides several times and slender eel-shaped ***sporozoites*** arise in about ten days. The oocytes now burst and liberate the sporozoites in the body cavity of the mosquito. They somehow reach the salivary glands of the mosquito and there wait for a chance to enter the body of man again when the mosquito bites him.

Significance of the complicated life cycle.—The complicated life-cycle of the malarial parasites is an adaptation for an endoparasitic mode of life. An endoparasite cannot continue indefinitely in the same individual of its host. The parasite is a drain on the vitality of the host. The metabolic waste products of the parasites have often a toxic effect on the host. Sooner or later the host is destined to be killed due to the cumulative effect of the loss of vitality and toxins, as well as destruction of vital organs or tissues. The death of the host means death of the parasite too, unless the latter manages to leave the host before it dies. An endoparasite is thus faced with the very difficult problem of escaping from the dying host and seeking another healthy individual.

The malarial parasite has managed to solve this problem with the help of Anopheles. Clearly very highly prolific reproduction is an advantage in this case. The enormous numbers of offsprings produced by schizogony ensure that a few at least are sucked up by the mosquito. Again the high fecundity of sexual reproduction followed by sporogony similarly ensures that at least a few will manage to get introduced into a healthy man.

The necessity for high fecundity is due to numerous uncertainties. The parasite can develop only in the females of Anopheles mosquito but not any other kind of mosquito. Even then not all species of Anopheles favour its development. Only some species are able to transmit malaria. Of the several individuals of the right species of Anopheles which might suck

the blood of man and take in the malarial parasites, none may find an opportunity of again biting a healthy man when the sporozoites are ready, waiting in its salivary glands. Unless a very large number of offsprings are produced the chances of survival for the malarial parasites are very few.

Anopheles that act as intermediate hosts.—The malarial parasites cannot develop in all species of Anopheles equally well. In some of them they cannot at all survive. The following species of Anopheles are important transmitters of malaria : *Anopheles culicifacies*, *A. stephensi*, *A. minimus*, *A. fluviatilis* and *A. sundaicus*. The extremely common *A. subpictus* does not appear to have much relation to the incidence of malaria.

SYNOPSIS OF THE LIFE-HISTORY

I. ***In man***

1. Sporozoites attack erythrocytes.
2. Inside the corpuscles they become trophozoites
3. Trophozoites grow and become schizonts
4. Schizonts reproduce asexually by multiple fission and give rise to several generations of merozoites
5. Merozoites escape from the dead corpuscles and attack fresh ones
6. Trophozoites become gametocytes
7. The gametocytes are sucked up by the Anopheles.

II. ***In Anopheles***

1. The gametocytes become macrogametes and microgametes
2. The microgametes fertilize the macrogametes
3. The zygotes become ookinete
4. Ookinete burrows to the surface of the gut and becomes encysted as oocyst
5. The oocyst produces sporoblasts
6. Sporoblasts produce sporozoites
7. Sporozoites reach the salivary glands and are introduced into man with the saliva when the mosquito sucks blood.

CILIATA

The CILIATA possess ***cilia*** or fine hair-like processes of the ectoplasm as locomotor organelles (Fig. 123). They differ from the Sarcodina and Mastigophora in the greater differentiation of structure. Defensive organelles exist. Nuclei are two. Reproduction is also relatively advanced.

Ciliates inhabit fresh and salt waters. Some are sessile and many are parasitic. *Balantidium coli* occurs in the alimentary canal of man and

Opalina (Fig. 123) in that of the frog. Some of the encysted Ciliata are capable of withstanding extremes of temperature like $-180°C$ and $+106°C$.

The Ciliata are also often called ***Infusoria*** because they breed in infusions of hay and dry leaves.

Classification.—

Class CILIATA—Cilia locomotor organelle.

Subclass I. *PROTOCILIATA*. Without cytostome; the two nuclei are not differentiated. Example: *Opalina*

Subclass II, *EUCILIATA*. With cytostome: macro and micronuclei present.

Order 1. HOLOTRICHA. Cilia uniformly distributed.

Suborder 1. *Gymnostomata*. Cytostome closed except at feeding. Example: *Didinium*

Suborder 2. *Trichostomata*. Cytostome permanently open. Example: *Paramecium*.

Order 2. SPIROTRICHA. At least the ventral side with cilia.

Suborder 1. *Heterotricha*. Examples: *Balantidium* and *Stentor*.

Order 3. PERITRICHA. Stalked, body cilia absent, oral cilia present. Examples: *Vorticella*, *Epistylis*.

4. PARAMECIUM

Occurrence and systematic position.—The *Paramecium* is a free-swimming complex protozoan, which lives in fresh-water rich in dead and decaying vegetable matter. It is abundant in waters in which there is plentiful of bacteria. It is common in most stagnant waters and in infusions of hay, leaves, etc.

Paramecium is a cosmopolitan Infusorian. A few species are marine. There are several species, of which three are quite common in India: *Paramecium aurelia*, *P. bursaria* and *P. caudatum*. *P. caudatum* is of world-wide distribution and is the most abundant of all in India. It is found at all times in any stagnant water containing dead leaves. *P. aurelia* is smaller than *caudatum* and *bursaria* and often contains numerous small algae within.

The following is the systematic position of *Paramecium*:

Phylum PROTOZOA
Subphylum *CILIOPHORA*
Class CILIATA
Subclass *Euciliа*
Order Holotricha
Suborder Trichostomata
Family Parameciidae
Genus *Paramecium*
Species *caudatum*.

Structure.—The paramecium differs from amoeba in having a constant shape. The cell body is elongated and somewhat flattened. It has a broader and rounded anterior end and a gradually tapering posterior end.

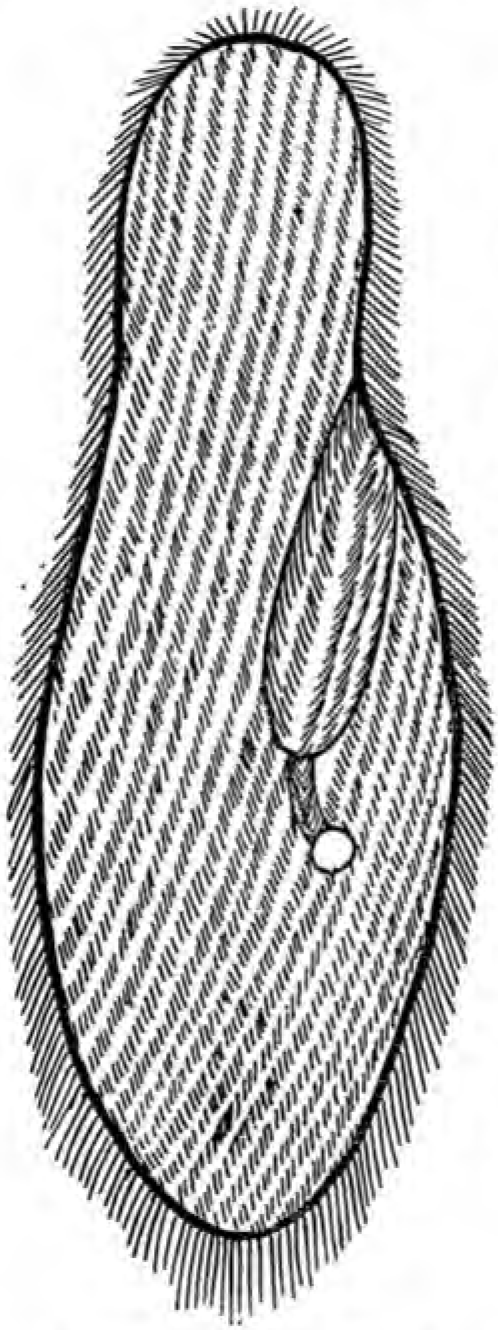


FIG. 128. *Paramecium caudatum* in surface view to show the cilia arranged in rows.

It is widest just beyond the middle. The body outline has been fancifully compared to the sole of a slipper and hence paramecium is often also called slipper-animalcule.

It has a ventral surface indicated by the ***oral groove***. It begins from the anterior end and runs diagonally back nearly to half the way on the ventral surface. It ends in the median line in a large funnel-shaped depression, the ***cytostome***. The cytostome opens in to a short ***cytopharynx*** ending in the endoplasm. Behind the cytopharynx is a

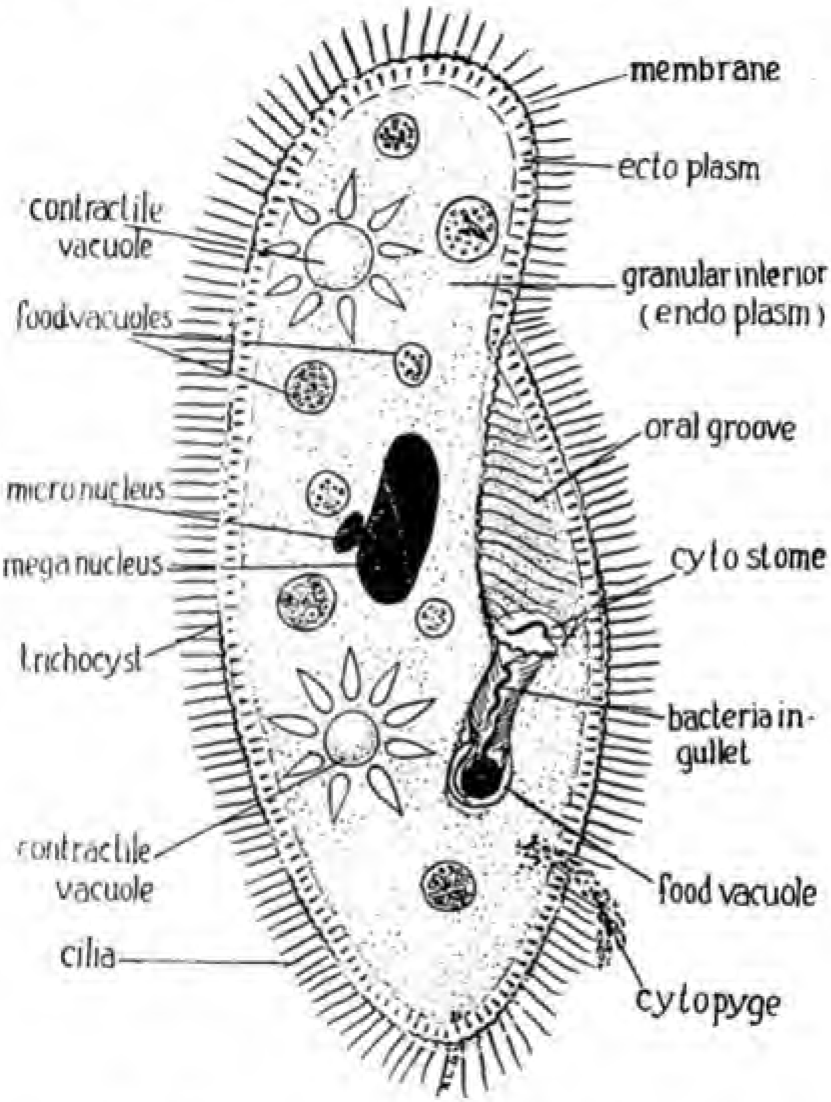


Fig. 129. *Paramecium caudatum.* Structure.

temporary ***cytopyge*** or cell-anus. Like euglena, paramecium possesses a thin elastic pellicle. When the paramecium is treated with silver salts and specially prepared for the micriscope, the pellicle shows hexagonal cup-like areas bounded by ridges (Fig. 130). From the centre of each of these areas projects a fine hair-like process called ***cilium*** (pleural cilia) of the ectoplasm. Each cilium is connected to a ***basal granule*** beneath the pellicle. The granules are joined by longitudinal fibrils. The granules

and the fibrils comprise the ***neuromotor*** co-ordinating system, resembling the nervous system of the frog. They co-ordinate the movements of the cilia. The cilia are distributed uniformly all over the surface in definite longitudinal rows (Fig. 128). The rows of cilia in the oral groove are fused together to form two longitudinal ***undulating membranes.*** The arrangement of cilia near the oral groove is such that a current is created in the direction of the cytostome.

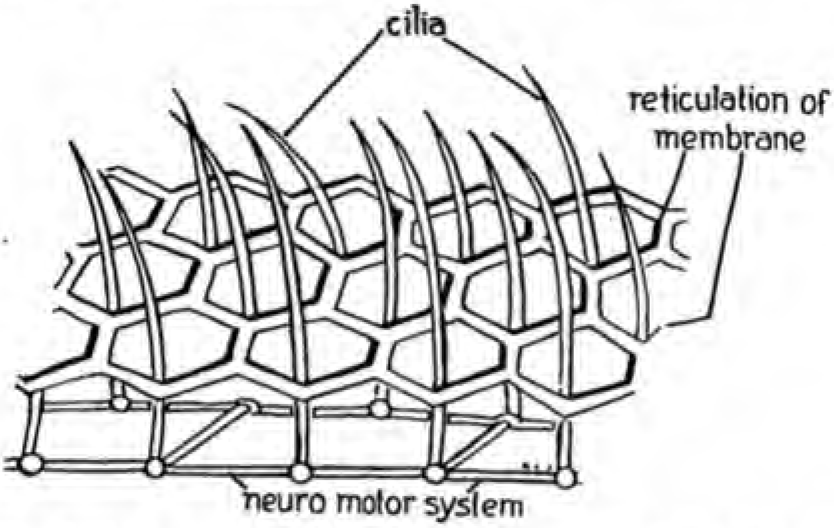


FIG. 130. Surface view of the pellicle of *Paramecium* showing the cilia centered in hexagonal areas and connected together by the neuro-motor system. (*Adapted from Lund*).

The cytoplasm is differentiated into ecto- and endoplasms. Just below the pellicle the ectoplasm contains numerous cavities, the ***trichocysts,*** filled with a liquid. If the paramecium is irritated, the trichocysts explode and long filaments stick out. The trichocysts are organelles of defence and perhaps also of offence. The endoplasm contains fat droplets, food vacuoles, two contractile vacuoles and two nuclei. The larger of the two is the ***macronucleus*** or ***meganucleus*** and the smaller ***micronucleus.*** The macronucleus governs the vegetative functions of the animalcule and the micronucleus takes part in the reproduction of paramecium. The endoplasm also contains mitochondria and Golgi bodies.

Motion and locomotion.—The most striking feature of paramecium is the speed of its movements. A paramecium can bend round an obstacle and squeeze itself into spaces narrower than its body. It is always rolling over itself. The cilia are constantly "beating" or waving. All the cilia in a row do not beat at the same time but one after another, so that a wave of beating passes by. Locomotion is brought about by the ciliary movement. The cilia beat backward, starting from the

anterior end. Just as the backward stroke of the oar carries a boat forward, the backward beat of the cilia carries the paramecium forward. The cilia however do not strike straight back but obliquely so. This causes the paramecium to rotate on its own longitudinal axis as it moves forward Further, the cilia on the oral groove beat faster and more vigorously than the rest, so that the anterior end swerves dorsally. The result of all these combined movements of forward push, axial rotation and swerving is that the paramecium follows a spiral path, (Fig. 131)

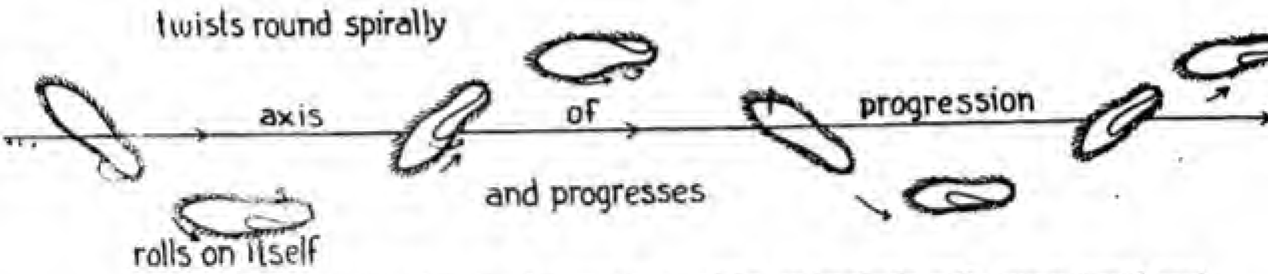


FIG. 131. Locomotion in *Paramecium*. The animalcule rolls upon itself and, swims in a spiral manner, so that the asymmetrical body moves in a direct line. (*Modified from Jennings*).

rotating not only on the body axis but also, round and round the axis of the path of locomotion. When the animalcule wants to swim backward, the cilia beat forward and all the movements are reversed.

Nutrition.—The food of paramecium consists largely of bacteria, smaller protozoa, yeast and small algae. The food capturing mechanism is much better developed than in amoeba. The constant beating of the cilia in the oral groove drives a current of water containing food particles toward the cytostome (Fig. 132). The undulating membrane sweeps the food particles with a quantity of water down the cytopharynx toward the cytostome. A food vacuole is thus formed in the endoplasm. When this vacuole grows up to a certain size, it pinches off and begins to circulate in the endoplasm due to the streaming movement, ***cyclosis***, of the endoplasm. Another vacuole now begins to appear. The food vacuole is at first acidic and as degestion of the contained food progresses, it becomes alkaline. The undigested matter is forcibly ejected by the cytopyge.

Respiration and excretion.—Respiration takes place on the surface of the cell body. The contractile vacuoles regulate the water-content and also expel other excretory products. Each contractile vacuole is fed by about a dozen ***radial canals***. When the vacuole attains a maximum size, it contracts and discharges its contents to the outside through the pellicle.

Reproduction.—Paramecium reproduces by 1. transverse binary ᴉn, 2. conjugation, 3. autogamy and 4. endomixis.

Binary fission.—The micronucleus divides into two by mitosis. : macronucleus divides into two by amitosis. A new cytopharynx and new contractile vacuoles appear. Finally the cytoplasm divides trans-sely into two. The two daughter paramecia are equally large. They d and grow before dividing in the same way in their turn. Binary fission

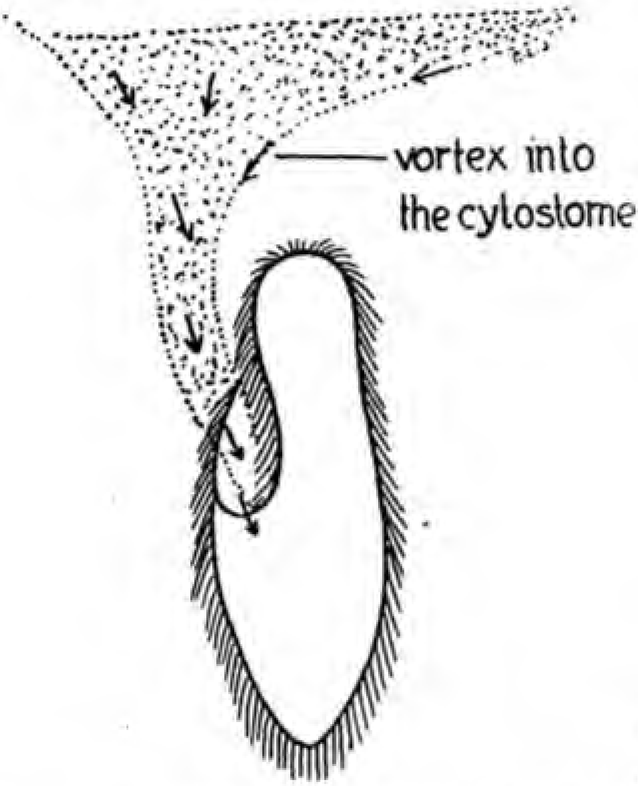


FIG. 132. Paramecium "Sampling" the water in front by creating a vortex into the cytopharynx through ciliary action before starting to move in a direction. (*Adapted and modified Jennings*).

takes place nearly four times in a day, so that in one day sixteen new paramecia arise from a single parent. Within a month the enormous number of 280,000,000 individuals can be produced if all the offsprings survived and if conditions were favourable.

Conjugation.—Reproduction by binary fission cannot go on indefinitely in the paramecium. After a certain number of generations, some sort of senile degeneration of the macronucleus sets in. The paramecium becomes depressed. Many individuals die and binary fission ceases. The paramecium is revitalised and given a new lease of life by conjugation.

In conjugation (Fig. 133) a pair of paramecia come together temporarily, exchange the micronuclear material and separate revitalised for a fresh cycle of binary fission. Two similar individuals adhere to one another by their ventral surfaces, with their oral grooves in close apposition.

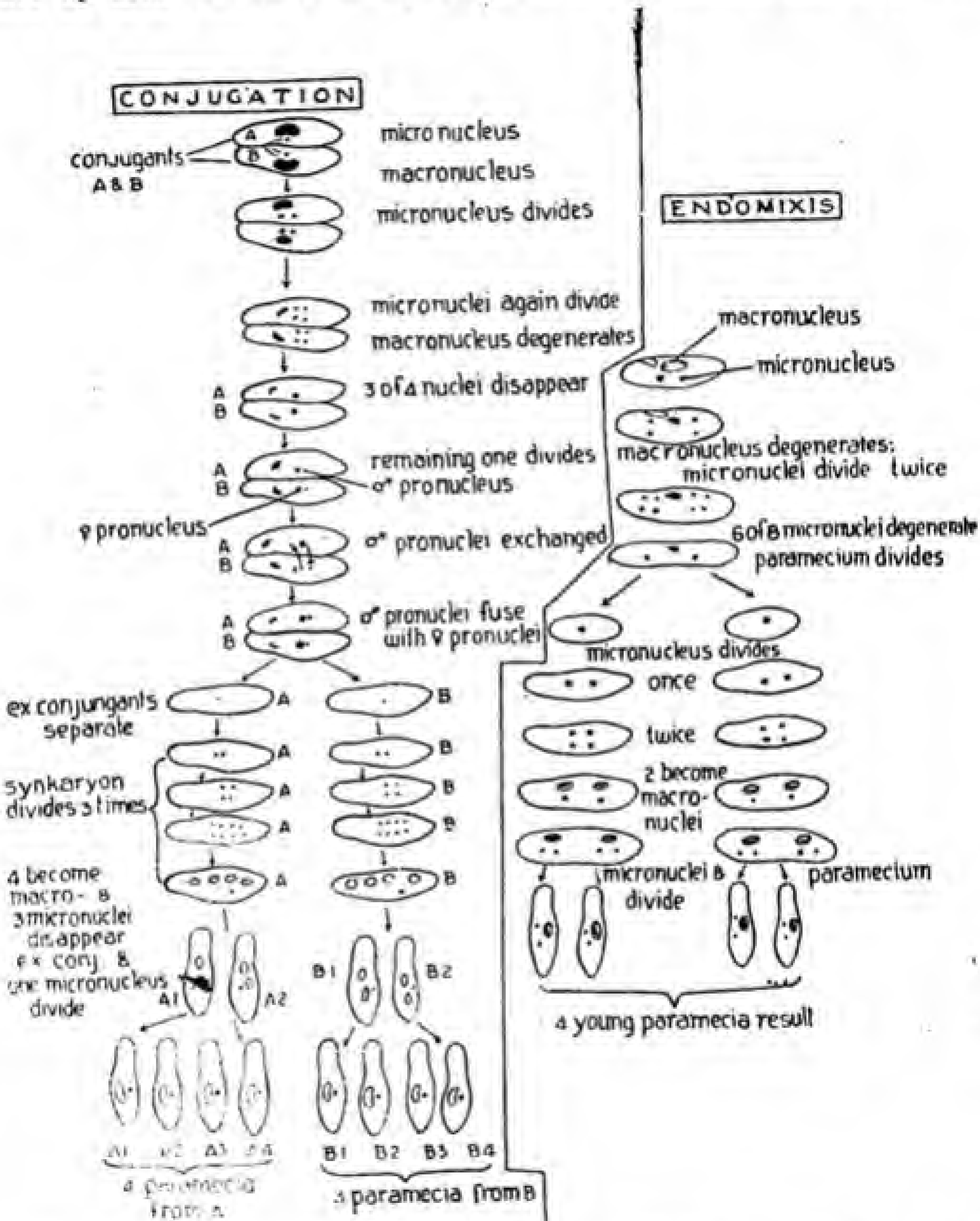


FIG. 133. Diagram of conjugation in *Paramecium caudatum* and endomixis in *P. aurelia.*

A protoplasmic bridge connects the two. The micronucleus of each leaves its position by the side of the macronucleus and swells up. The macronucleus disintegrates and disappears. In each of the conjugating individuals the swollen micronucleus divides into two by mitosis. The resulting halves

gain divide mitotically into two, so that four micronuclei result. Three of hese degenerate. The remaining micronucleus again divides into two ***pronuclei***. One pronucleus from each of the ***conjugants*** migrates to the other by way of the protoplasmic bridge The migrating pronucleus is called "male" nucleus and the stationary one is the "female" nucleus. The male pronucleus of one conjugant goes to the other and fuses with the female pronucleus, thus giving rise to a ***synkaryon*** or zygote nucleus. The paramecia now separate and swim away as ***ex-conjugants.***

The zygote nucleus of each ex-conjugant divides by mitosis three times, giving rise to eight micronuclei. Four of these become enlarged to macronuclei. Of the remaining four, three degenerate. The single micronucleus which is now left divides once more twice and produces four micronuclei. At the same time the paramecium also divides into two twice, giving rise to four paramecia, each with one macro and one micronucleus. Thus from each ex-conjugant four revitalised paramecia arise.

Conjugation is *not* sexual reproduction, because the conjugating individuals are identical and there is no differentiation of sex. The so-called male and female pronuclei do not differ from each other in any way. In conjugation the union of two individuals is temporary and there is also no fusion of the two cells. In sexual reproduction there is always a fusion of two cells. Conjugation is thus a temporary union for mutual exchange of nuclear substance. It is also called ***syngamy*** or marriage of the like.

The factors that determine conjugation are not still clearly understood. Only the individuals of certain races can conjugate. Paramecia descended from a single individual do not conjugate with one another.

SYNOPSIS OF CONJUGATION

I. ***Nuclear changes in the conjugants***

1. Two paramecia unite by their oral grooves.
2. Macronucleus disintegrates.
3. Micronucleus undergoes mitosis twice; three of the resulting micronuclei degenerate.
4. The remaining micronucleus divides into two pronuclei.
5. One of the pronuclei of each goes over into the other conjugant and fuses with its stationary pronucleus.

II. ***Changes in the ex-conjugants***

1. Zygote nucleus divides thrice to give rise to eight micronuclei.
2. Four of these form four macronuclei and three of the rest degenerate.

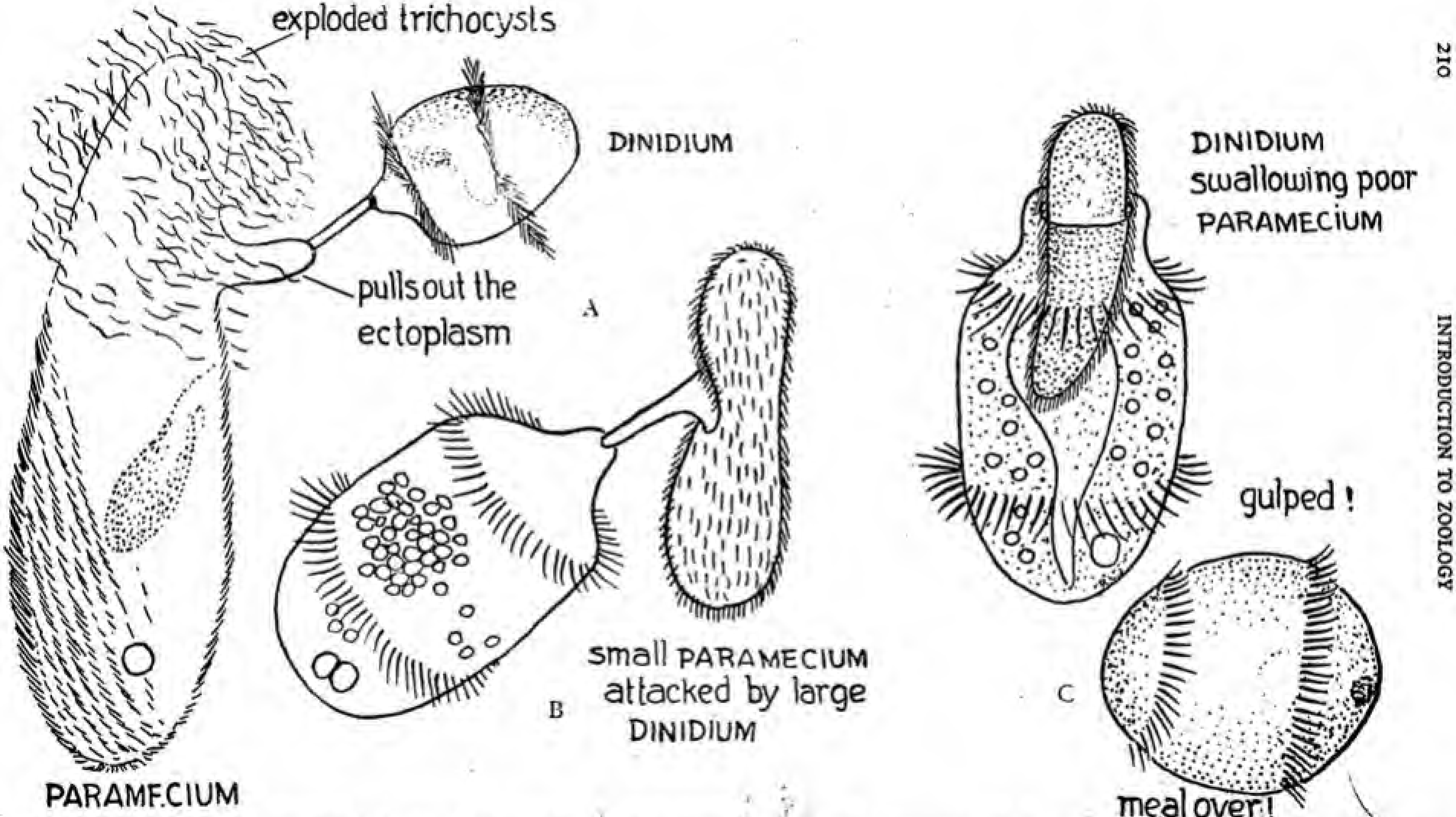


FIG. 134. *Paramecium* being attacked and devoured by *Dinidium*, another Protozoan. A. A large *Paramecium* throwing out trichocysts in defence, as a *Dinidium* is pulling out its ectoplasm. B. A large *Dinidium* attacks a small *Paramecium*. C. The Paramecium is disappearing down the cytopharynx of the *Dinidium*. (R[illegible] and modified from Wolcott after Mast and Calkins).

3. The remaining one divides twice and produces four micronuclei.
4. The ex-conjugant paramecia divide twice and produce four paramecia, each with one macro and one micronucleus.

Autogamy.—Autogamy is a sort of self-fertilization, in which the micronucleus divides several times and is then formed once more by the reunion of the divided bits.

Endomixis.—The macronucleus disintegrates. The micronucleus divides twice. Three of the resulting micronuclei degenerate. The remaining micronucleus again divides into two and with it the paramecium also divides into two. Each paramecium has one micronucleus. This now divides into two and these again divide, thus producing four micro-

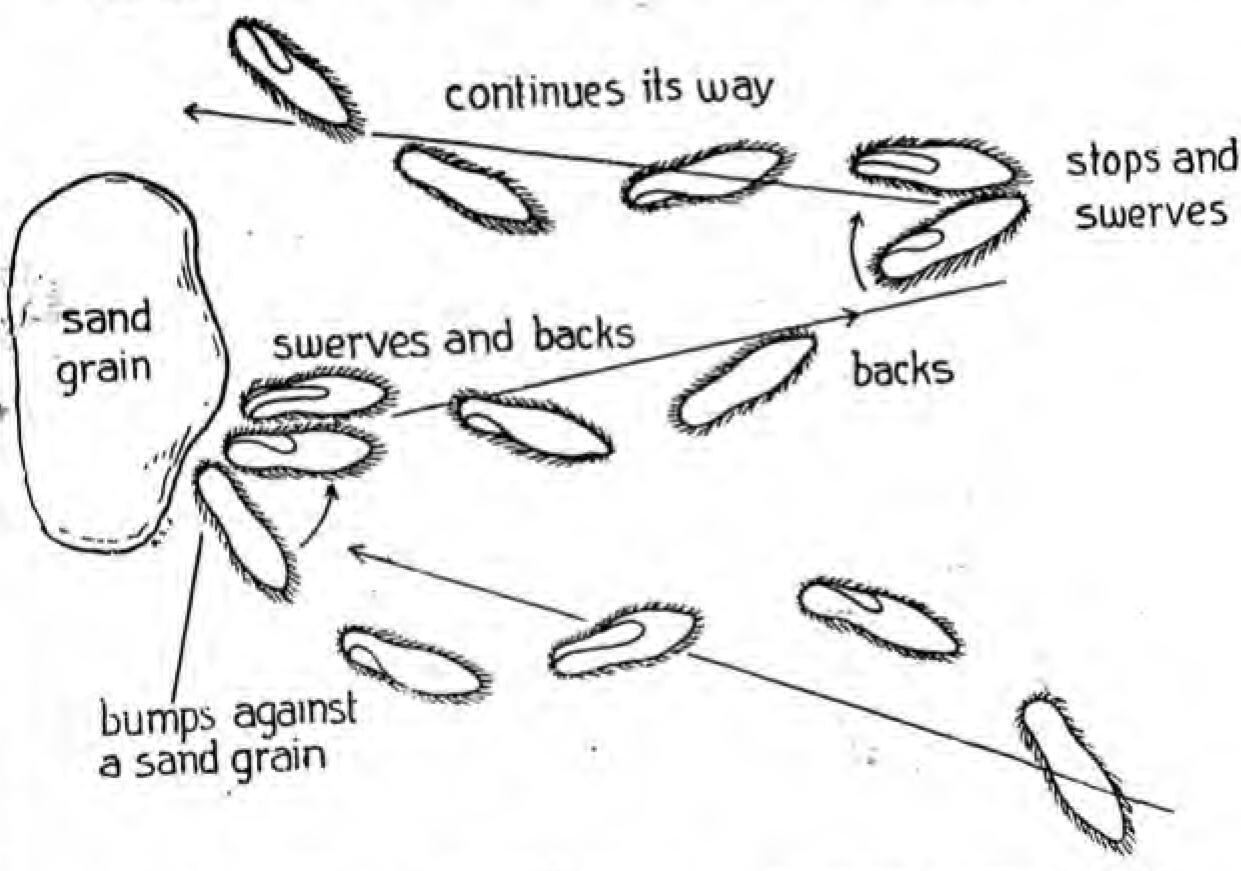


FIG. 135. Avoiding reaction in *Paramecium*. *Paramecium* is constantly moving rapidly, bumping against various obstacles, changing its path and moving again. (*Modified from Jennings*).

nuclei. Two of these become macronuclei and the other two micronuclei. The animal divides once again into two, each now having the usual one macronucleus and one micronucleus.

Endomixis takes place once in about a month after numerous binary fissions.

Natural enemies.—Paramecium is attacked by several natural enemies. Amoeba often engulfs and kills small paramecia. The infusorian *Dinidium* eats almost nothing but paramecia and it is the worst enemy. The *Dinidium* (Fig 134) has a snout-like prolongation armed with trichocysts. The snout pierces a paramecium, which is then gulped whole. Another peculiar Infusorian from India, *Sphaerophrya* is a parasite in paramecium.

Behaviour.—Paramecium is most usually roaming about hither and thither and bumping into all sorts of obstacles. It then backs up, swerves a little and pushes ahead again (Fig. 135. This ***avoiding reaction*** is exhibited against not only mechanical obstacles, but also against excessive heat or cold, irritating chemicals, natural enemies and so on. The beating of the cilia sets up a constant cone-shaped current towards the oral groove (Fig. 132). This current actually gives advance information of the hot or cold water or irritant chemicals far ahead and the paramecium has time to swim back, without actually colliding with it and injuring itself. Paramecium in some unknown way reacts to gravity, because it is able to swim with its anterior end up when rising to the surface of the water. It has a limited power of "learning" by trial-and-error-method.

Comparison of amoeba and paramecium.—The paramecium is more advanced than the amoeba in several respects. There are complex organelles for speed in locomotion and far more efficient capturing of food. Reproduction is also much more complicated.

AMOEBA	PARAMECIUM
1. Shape not constant	1. Shape constant
2. Plasmolemma structureless	2. Pellicle reticulate
3. Pseudopodia present	3. Pseudopodia absent
4. Nucleus single	4. Nucleus two
5. Contractile vacuole single	5. Contractile vacuoles two
6. No definite spot for ingestion	6. Oral groove, cytopharynx and cytostome serve for ingestion
7. Egestion at any spot on cell body	7. Egestion at cytopyge
8. No neuro-motor co-ordinating system	8. Neuro-motor co-ordinating system controls the cilia
9. Locomotion slow and irregular	9. Locomotion rapid and regular
10. Reproduction solely by binary fission and spore formation	10. Reproduction by binary fission, conjugation, endomixis and autogamy.

OTHER CILIATA

Balantidium coli lives in the large intestine of man and rectum of the pig and monkey. It multiplies by transverse fission, conjugation and encystment and causes diarrhoea in man.

RESUME

I. Protozoa

1. The Protozoa are unicellular organisms without true tissues and organs.
2. All the vital activities are carried on within the limits of the single cell.
3. Locomotion is effected by streaming (pseudopodia) or by lashing movements of flagella or cilia.
4. Nutrition is effected either by engulfing or ciliary action.
5. Excretion is effected by contractile vacuoles.
6. Reproduction takes place by binary or multiple fission, sporogony, conjugation, endomixis, etc.
7. Many Protozoa are free-living but others are parasites in various animals. Many are responsible for fatal human diseases.
8. The Protozoa are classified into 1. Sarcodina, 2. Mastigophora, 3. Sporozoa, 4. Ciliata and 5. Suctoria.

II. Amoeba

9. The Amoeba belongs to Sarcodina and occurs in fresh-water. Some, like *Entamoeba histolytica*, cause diseases in man.
10. The Amoeba has no constant shape. It moves and engulfs food by pseudopodia.
11. It reproduces by binary or by multiple fission.
12. It is capable of reacting to various external stimuli and also exhibits a "will" of its own.

III. Euglena

13. Euglena differs from amoeba in having a constant shape and in the possession of organelles like flagellum, cytopharynx, etc.
14. Locomotion in euglena is by movements of the flagellum
15. The nutrition is both saprophytic and holophytic.
16. Euglena reproduces by longitudinal binary fission.

IV. Volvox

17. Volvox is a protozoan colony composed of somatic and germ cells.

V. Malarial parasites of man

18. Three species of human malarial parasites are common : *Plasmodium vivax* causes the tertian ague, *P. malariae* causes the quartan fever and *Laverania malariae* is responsible for malignant malaria.
19. The malarial parasites develop in two hosts : man the definitive host and female Anopheles the intermediate host.
20. They lack complex organelles and are greatly degenerated in structure but have a complex life-cycle as an adaptation for a parasitic life.
21. The asexual life-cycle is passed in man but the sexual cycle is completed in the female Anopheles.

VI. **Paramecium**

22. Paramecium inhabits fresh-water that is rich in decaying vegetable matter.
23. It is a slipper-shaped animalcule, covered by cilia, that help in locomotion and food-capturing. There is a neuro-motor system that controls ciliary action.
24. Reproduction is by binary fission, conjugation, endomixis and autogamy.
25. In conjugation two identical individuals meet temporarily, exchange their nuclear material and become re-vitalised.

CHAPTER VII

PORIFERA

Porifera.—The PORIFERA (meaning *pore bearer*) or sponges are lowly, multicellular, aquatic animals that are incapable of locomotion and resemble plants in general appearance. Most sponges are marine but many occur in fresh-water. They are widely distributed and abundant from low tide mark to depths of 3·5 miles. They form shapeless flat incrustations on stones and other objects or branched, vase-shaped or globose masses, often measuring 6 ft. high. Most of them are drab-coloured but some are bright red, yellow, blue, violet or black.

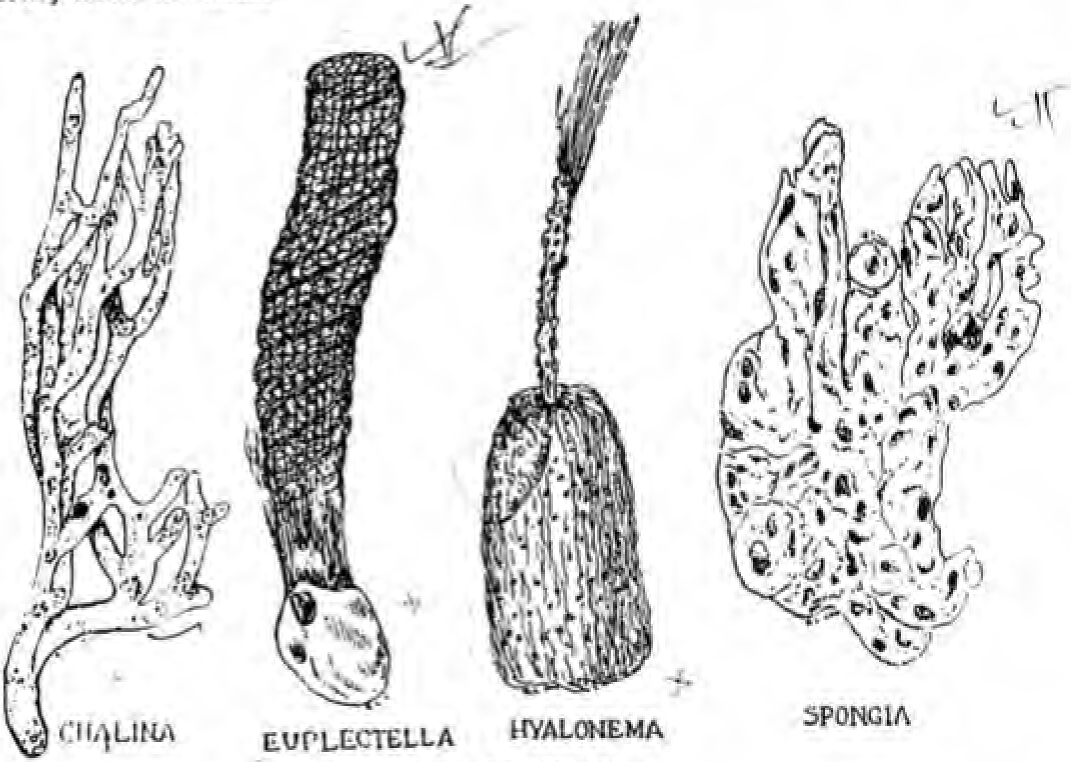


FIG. 136. Porifera.

Characters.—The phylum is recognized by the following characters :

1. Multicellular, diploblastic, solitary or colonial animals incapable of locomotion.
2. Body radially symmetrical or without symmetry.
3. Body wall with many pores and canals through which water flows.
4. Body wall with skeletal spicules of silicon, calcium, etc. (Fig. 137).
5. Cells imperfectly arranged into tissues. Interior surfaces with flagellate cells.
6. Without mouth, definite digestive tract or other organs.
7. Digestion wholly intracellular as in Protozoa.

8. Reproduction asexual by buds and gemmules or sexual by ova and sperms.
9. Larva free, ciliated.

Classification.—

Phylum **PORIFERA.** Many-celled, aquatic. Body with pores communicating with one or more internal canals, one of which is lined by collared flagellate cells. Skeleton of spicules. (Fig. 136)

Class I. CALCAREA. Marine. Spicules of lime, simple or triradiate.

Order 1. HOMOCOELA. General epithelium a single sac. Examples: *Clathrina, Leucosolenia.*

Order 2. HETEROCOELA. Epithelium lines canals. Examples: *Grantia, Sycon.*

Class II. HEXACTINELLA. Deep-sea forms. Spicules silicious. Examples: *Hyalonema, Euplectella.*

Class III. DEMOSPONGIA. Marine and fresh-water. Skeleton of spongin, silicious spicules present. Canal system complicated.

Order 1. TETRACTINELLIDA. Spicules tetraxons. Example: *Plakina.*

Order 2. MONAXONIDA. Spicules simple, fresh-water sponges. Examples: *Cliona, Spongilla.*

Order 3. KERATOSA. Skeleton of spongin. Example: *Euspongia* bath sponge.

Order 4. MYXOSPONGIA. Without skeleton. Example: *Oscarella.*

SYCON

Body wall – Sycon is a simple sponge. The body is essentially a hollow flexible branching cylinder, connected together at the base and to the substratum. The smooth surface presents under a hand lens polygonal elevated areas, separated by grooves. In these grooves are the minute pores called ***ostia*** or inhalent pores, through which a current of water enters the sponge. At the free end of each cylinder is the ***osculum*** or exhalent aperture, surrounded by a fringe. Water passes out of the sponge through the osculum. The lumen of the cylinder is the ***cloaca***.

The body wall comprises an external single layer of dermal epithelium of flattened cells and an inner layer of ***choanocytes*** lining the cloaca. The choanocytes are characteristic collared, flagellate cells resembling the Choanoflagellata (Protozoa). Between these two layers is a middle region containing the skeletal ***spicules*** (Fig. 137), the ***scleroblasts*** that secrete the spicules and connective tissue cells or ***collencytes***. Large ***archaeocytes*** or amoeboid cells, that are capable of migrating, also occur in the intermediate layer. The archaeocytes can give rise to other types of cells and are thus ***totipotent***. Sperms and ova also occur in the middle layer.

Canal System. – The canal system (Fig. 138) begins in the ostia on the surface. The ostia open into an ***incurrent canal***, that runs radially in the wall and ends blindly: it does not open into the cloaca. The incurrent canal communicates by ***prosopyle*** with the ***flagellate canal***, that lies

FIG. 137. Types of spicules of sponges.

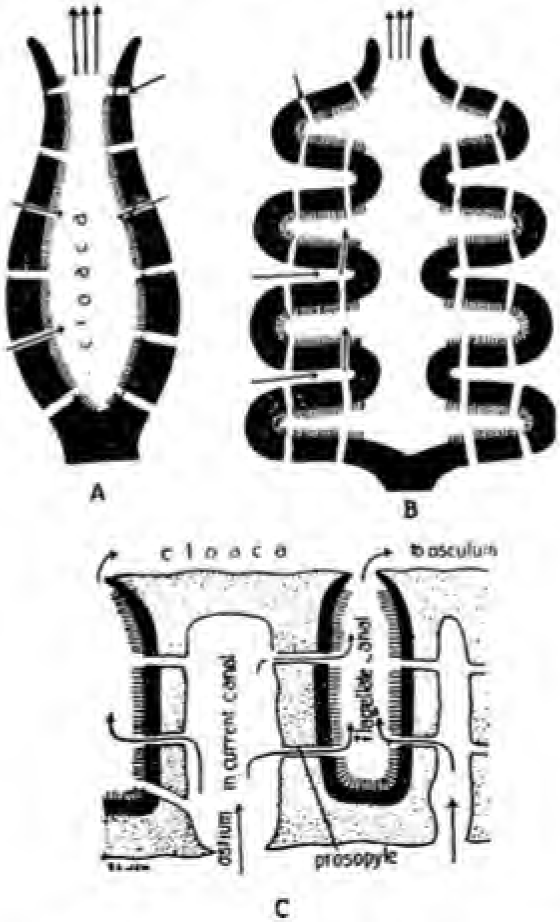


FIG. 138. Diagram of the canal system of sponge. A. Simple sponge. B. A complex sponge derived by infolding of the wall. C. Section of a part of the body wall of a sponge to show the flagellate and incurrent canals. (Dermal epithelium light, flagellate cells black; the arrows indicate the direction of water currents).

parallel to it. The flagellate canal is lined by collared cells, with flagella at the free ends. They include one or more vacuoles. The flagellate canal is closed externally but opens by a small ***apopyle*** into the ***excurrent canal***, also lined by flagellate cells. The excurrent canal opens into the cloaca. By the action of the flagella a current of water enters through the ostia and passes out of the excurrent canal into the cloaca and to the outside by the osculum. The choanocytes engulf the organic particles in the current, ingest and digest them.

Regeneration and Reassociation.—Sponges grow by budding and can readily replace lost parts. Sponges can be cultivated from cuttings like plants. Some sponges can be squeezed through silk, so that the cells separate. If these cells are allowed to settle down, they will ***reassociate*** and in course of time grow into a new sponge.

Reproduction and Development.—Asexual reproduction through external ***budding*** is common in sponges. By this means a colony is produced. ***Gemmule*** formation is another method of asexual reproduction. A ***gemmule*** is an internal bud that comprises groups of cells separated by membrane. The gemmule can withstand desiccation and most adverse conditions fatal to life. When favourable conditions return, it grows up into the sponge.

Sponges are ***hermaphroditic*** but are mostly ***protandrous***, i. e. the sperms mature before ova. Fertilization is within the parent, the sperms reaching by the water current. The ***blastomeres*** (Fig. 139) resulting from

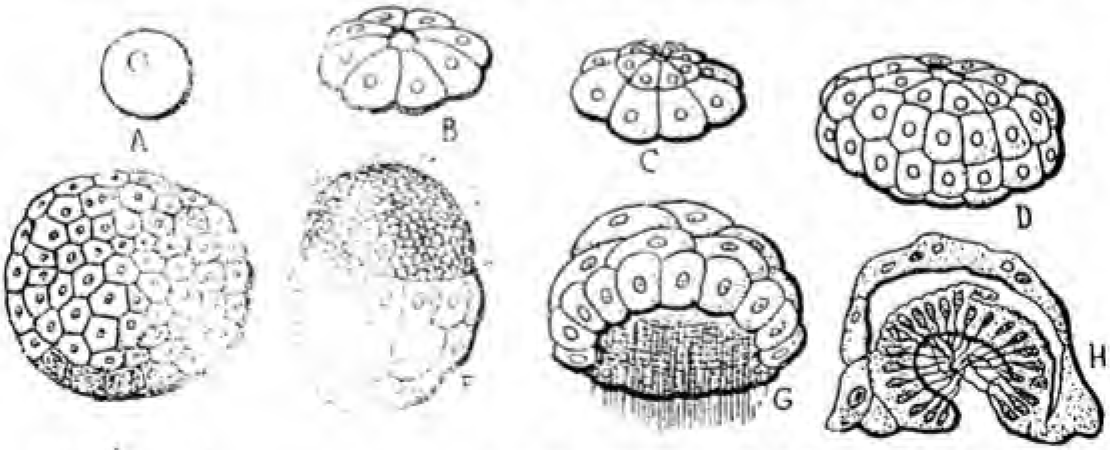


FIG. 139. [illegible] typical sponge. A. Zygote. B. 8-cell stage. C. 16-cell stage [illegible] and micromeres. D. Blastula. E. Late blastula, [illegible] swimming amphiblastula larva with ciliated upper pole. G. [illegible] section of the fixed larva that develops gradually into [illegible] (from Schulze).

the segmentation become arranged into an oval ***blastula***. The blastula is rounded at one end and flattened at the other. The cells at the rounded end

become granular. Those at the opposite end elongate and develop flagella. These columnar cells partly enclose the granular ones. The embryo breaks free and swims out into the sea by way of the osculum. The granular cells that remained so far invaginated, now come to lie on the surface. This stage is the ***amphiblastula*** larva. After a short free-swimming life, the larva settles down by the flagellated end. This end now gets invaginated within the granular cells and gives rise to choanocytes. The pores and canals make their appearance.

Affinities.—The Porifera resemble colonial Protozoa in many ways, especially the Choanoflagellata. They differ however in possessing a system of water circulation canals, skeleton and cellular differentiation. The sponges differ from metazoa in lacking a digestive tract, so that digestion is ***intracellular*** as in the Protozoa. The body layers of sponges do not correspond to the ectoderm and endoderm of metazoa: the ectoderm lines the cavities and functions as digestive cells. In the metazoa digestion is the work of endoderm. In the sponges the layer that first seems to be endoderm comes to lie on the surface and functions as ectoderm. There is no mesoderm. Sopnges are thus strictly not Protozoa and not Metazoa, but are considered to represent a side-line: the ***Parazoa***.

Relation to other animals.—Very few animals appear to relish sponges as food. A number of small animals like worms, crabs, fish, etc., resort to the cavities of sponges as a safe refuge from enemies. They also find a good source of food in the circulating water inside the sponge. Some sponges damage oysters by boring into their shell.

Man has used sponges for washing and bathing from very early times. The best bath sponges come from the Mediterranean, North America and from Australia. Sponge is also used in sound-absorbing wallboard.

RÉSUMÉ

1. The Porifera are multicellular aquatic animals incapable of locomotion.

2. The body is essentially a hollow cylinder, pierced by numerous pores, leading into a system of canals lined by collared flagellate cells, resembling the Choanoflagellata.

3. Water enters the sponge body through the pores and after passing through the canals escapes into hollow cavity of the cylinder, thence to the outside by way of the osculum.

4. There is no alimentary canal. The digestion of food is wholly intracellular as in Protozoa.

5. The body is reinforced by a skeleton of spicules of lime, silicon or spongin.

6. Reproduction is asexual by external budding or by internal gemmules and sexual by ova and sperms.

7. The zygote develops into a ciliated free-swimming amphiblastula larva, that settles down and grows into the sponge.

CHAPTER VIII

COELENTERATA

Coelenterata. The COELENTERATA (*koilos*=hollow, *enteron*=gut) are ***Metazoa*** or multicellular animals. The body of a metazoan consists either simply of two (diploblastic) or three (triploblastic) layers of cells—the ectoderm, mesoderm and endoderm or is all derived from these three layers. The cells that compose it are modified as different tissues. They differ from the colonial Protozoa in this division of labour and functional specialization and in the co-ordination of the activities of the cells.

The simplest Metazoa – Coelenterata – are merely alimentary canals enclosed by a skin. In their body there is only one cavity and that is the gut. There is no separate coelom or body cavity. The gut is at the same time the coelom and hence the name Coelenterata. This cavity is bounded by an endoderm and ectoderm only, i.e. the Coelenterata are diploblastic. They indeed correspond to the gastrula stage of the embryonic development of a higher animal like the frog. In other words the Coelenterata have developed only the alimentary canal and not other organ systems. The gut has only one opening which serves both as mouth and as anus.

The individuals of the phylum live either separately or in colonies. They are of two types: 1. ***polyp*** with a tubular body closed at one end and with finger-like ***tentacles*** surrounding the mouth at the other end; 2. ***medusa*** which is umbrella-shaped and has the mouth at the end of the handle of the umbrella. Their body is radially symmetrical. They all have stinging cells with which they paralyze their prey.

The Coelenterata are all aquatic and mostly marine. They are widely distributed everywhere. They comprise the hydroid polyps, medusae, jellyfishes, sea-anemones, corals, etc. Except the jellyfishes and some of the hydroid polyps, the rest of the phylum lead a sedentary life and often form plant-like colonies. The corals have a calcareous skeleton that forms the well known coral reefs and builds coral islands. Some of the corals are used in jewellery and in ayurvedic medicine.

Characters.—The Coelenterata are recognized by the following characters:

1. Diploblastic, multicellular, radially symmetrical.
2. Body without head, not segmented and without coelom. A single cavity serves both as digestive tract and body cavity.

3. Mesogloea slight or abundant between the ectoderm and endoderm.

4. Nematocysts present in ectoderm and or in endoderm.

5. Muscle fibres, horny or calcareous skeleton in the body wall.

6. Mouth surrounded by tentacles, richly supplied with nematocysts.

7. Enteron simple, branched or divided by septa.

8. Anus absent.

9 Digestion both intercellular as in Metazoa and intracellular within food vacuoles as in Protozoa.

10. No special organs of circulation or respiration.

11. Scattered unpolarized nerve cells in the body wall forming a nerve net. Rarely with statocysts.

12. Reproduction by asexual budding in the usually fixed polyp stage alternating with sexual usually free medusa stage.

13. Segmentation holoblastic. Larva a ciliated planula. Blastopore forms the mouth.

Classification.

Phylum COELENTERATA. Diploblastic, aquatic, radially symmetrical; with a single cavity having only a mouth but no anus; tentacles and stings present

Class I. *HYDROZOA*. Medusa with velum; polyp without endodermal folds.

Order 1. LEPTOLINAE.

Suborder i. Anthomedusae. Polyp without theca. Example: *Hydra*.

Suborder ii. Leptomedusae. Polyp with theca. Example: *Obelia*.

Order 2. HYDROCORALLINA. With massive calcareous skeleton. Example: *Stylaster*.

Order 3. SIPHONOPHORA. Floating. Examples: *Physalia* Portugese-man-of-war, *Velella*, *Porpita*.

Class II. *SCYPHOZOA*. Medusae without velum; polyp with four endodermal folds.

Order 1. STAUROMEDUSAE. Vase-shaped medusae. Example: *Haliclystus*.

Order 2. DISCOMEDUSAE. Saucer-shaped medusae. Example: *Aurelia*.

Class III. *ANTHOZOA*. Polyps only.

Subclass 1. Zoantheria. Numerous tentacles and mesenteries.

Order i. ACTINARIA. Solitary, without skeleton. Examples: *Metridium* and *Edwardsia* sea-anemones.

Order ii. MADREPORARIA. Colonial forms with calcareous skeleton. Examples: *Meandrina, Favia, Madreporia, Fungia*, etc. stone corals.

Subclass 2. Alcyonaria. With eight mesenteries and branched tentacles

Order i. ALCYONACEA. Skeleton of spicules. Examples: *Tubipora* organ-pipe coral, *Alcyonium* dead-man's finger.

Order ii. GORGONACEA. Tree-like. Examples: *Gorgonia* sea-fan, *Corallium* red coral.

Order iii. PENNATULACEA. Example: *Pennatula* sea-pen.

1. HYDRA—A simple Metazoan

Occurrence and systematic position.—The hydra is a fresh-water polyp, which is widely distributed all over the world. It occurs in ponds and

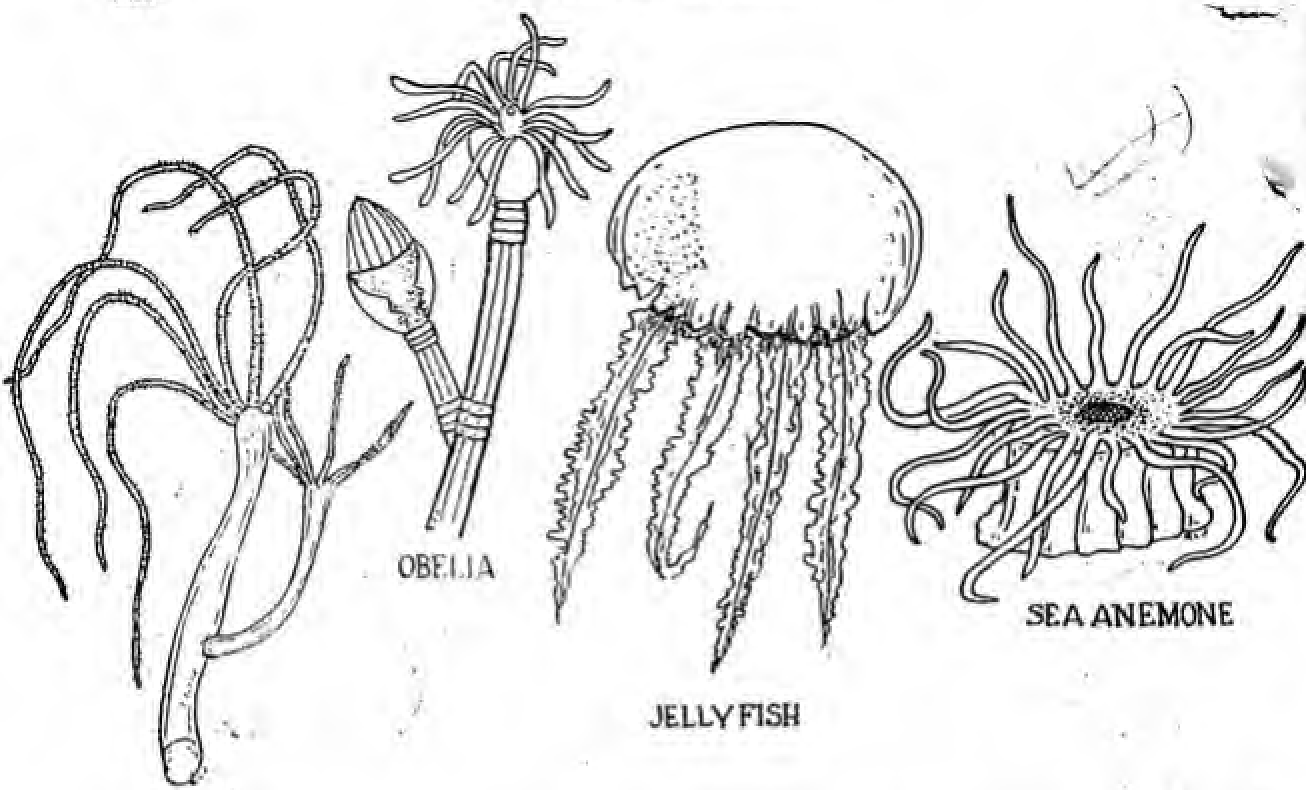


FIG. 140. Phylum Coelenterata. *Hydra* is a common fresh-water polyp. *Obelia* is a marine polymorphic colony. Jellyfishes float passively on the surface of the sea. Sea-anemones grow on the sea bottom attached like plants.

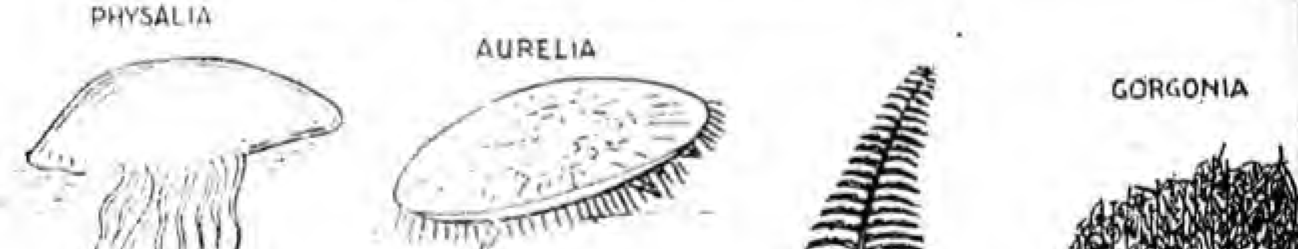


FIG. 141. Phylum Coelenterata. *Physalia pelagica*, the "Portugese-man-of-war" is also called 'blue-bottle'. It is one of the best known Siphonophora. The swimming bells are replaced by elongated gas-filled bladders, carrying below the polyps. It is common in warm seas. It causes unpleasant stings in bathers. *Aurelia aurita* is a common jellyfish that is often stranded in thousands on the beach. *Pennatula*, the so-called sea-pen, is a feather-like form with many polymorphic polyps along the sides. *Gorgonia*, the sea-fan is a horny coral. *Tubipora*, the organpipe coral is another horny coral.

all clean permanent fresh-water tanks and lakes rich in aquatic vegetation. It usually sticks to stones and plants under the surface of water.

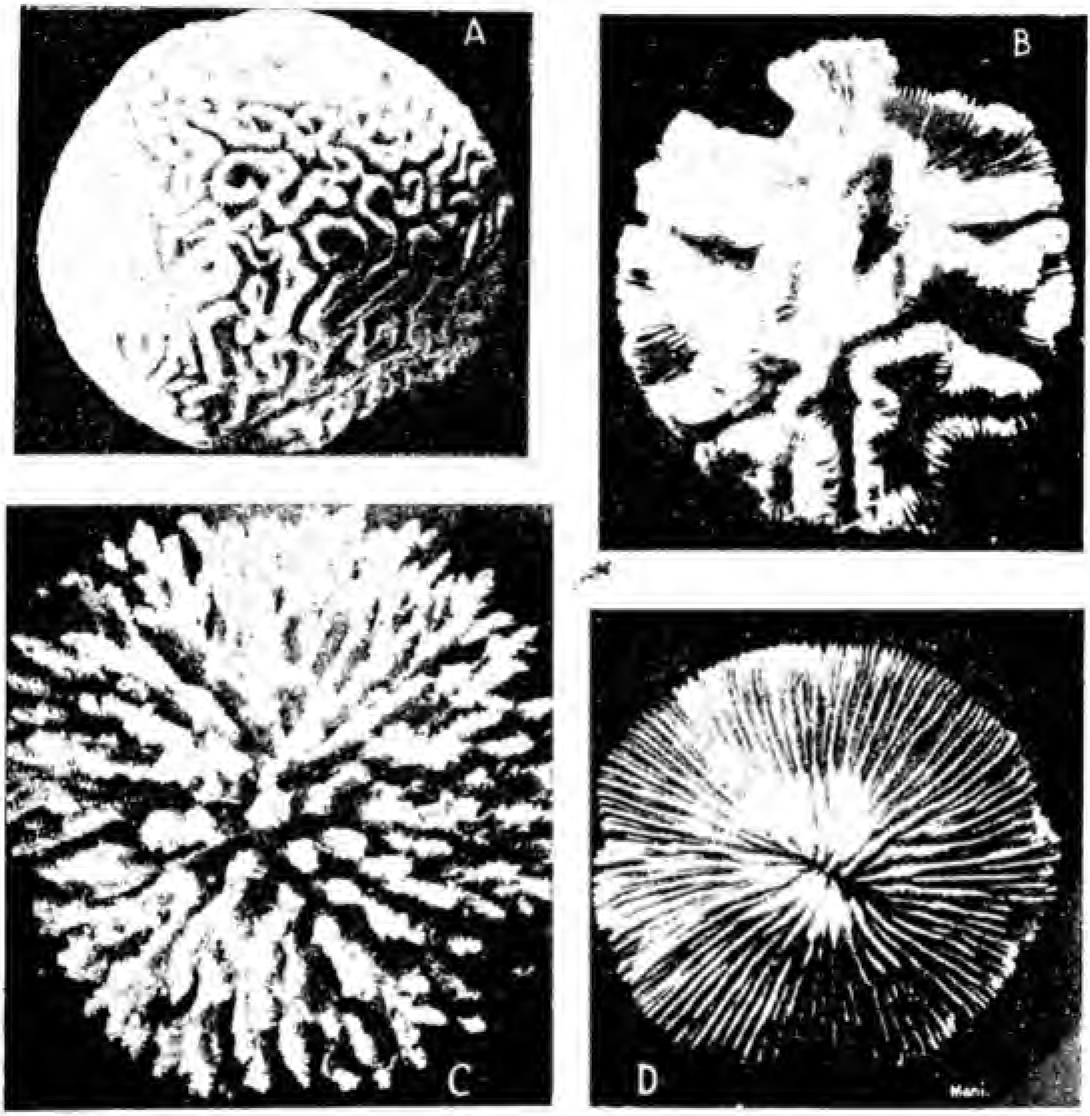


FIG. 142. Phylum Coelenterata. Some common types of corals that occur in the Indian waters. A. *Meandrina*, the brain coral. B. *Meandrina* the [illegible] coral. C. *Madrepora* the branching coral. D. *Fungia* the mushroom coral. (*Original photograph of specimens in the Zoology Museum, St John's College, Agra*).

Several species of hydra are known from the world. *Hydra vulgaris* (formerly called *Hydra grisea*) is a brown or orange species common in Europe, North America and all over tropical Asia. It is very abundant throughout India in stagnant waters. *Pelmatohydra oligactis* (formerly wrongly called *H. fusca* and *H. oligactis*) is another species common in Europe, North America and the Punjab. It differs from *Hydra vulgaris* in being slightly swollen near the tip and in its longer tentacles.

Chlorohydra viridissima (formerly called *Hydra viridis*) is quite common in Europe and America but has not so far been found in India Its green colour is due to the green alga *Zoochlorella* which lives within its body in a sort of mutual friendly relationship called ***symbiosis.***

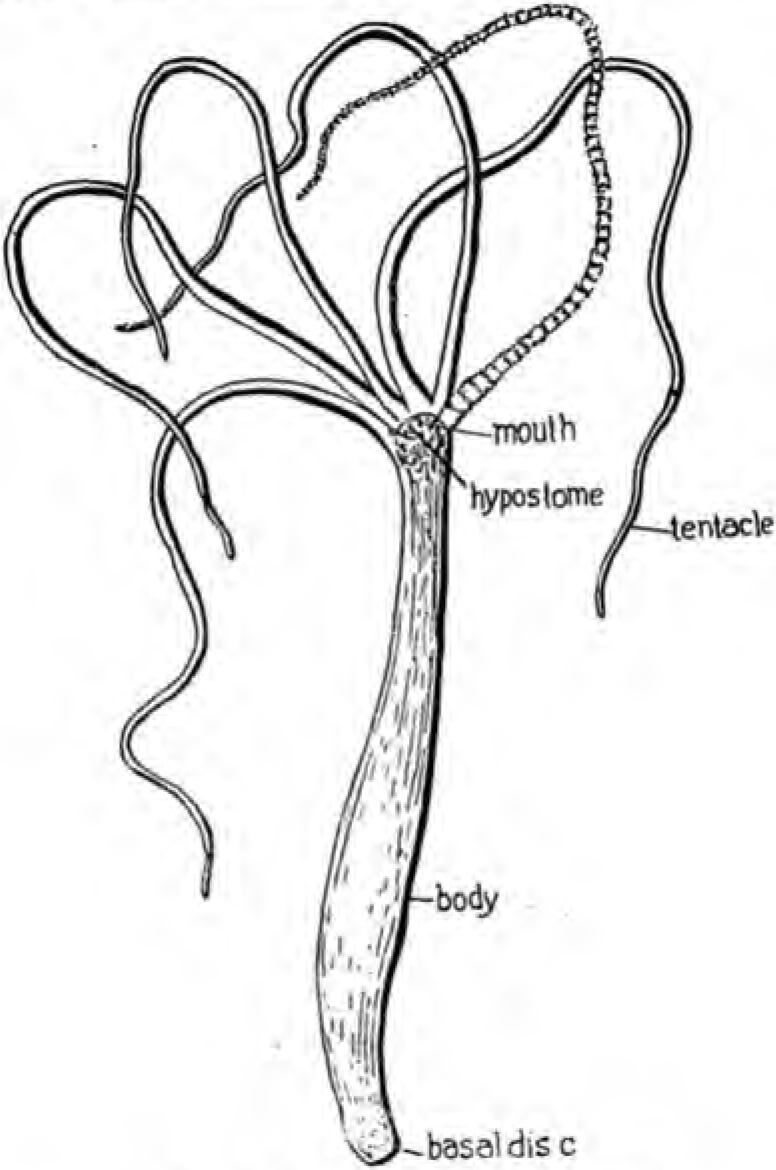


FIG. 143. *Hydra* External features.

The systematic position of *Hydra vulgaris* is as follows :

Phylum COELENTERATA
Class *HYDROZOA*
Order LEPTOLINAE
Suborder Anthomedusae
Family Hydriidae
Genus *Hydra*
Species *vulgaris*.

Structure.—The body of a hydra is a slender, cylindrical flexible tube, about 10 mm. long and closed at one end to form a ***basal disc*** for attachment to the substratum. It is radially symmetrical. A mouth is situated on a conical ***hypostome*** at the free end. The mouth is surrounded by six to ten slender, hollow, highly flexible ***tentacles***. The mouth opens directly into a large ***enteron***. The cavities of the tentacles communicate with the enteron. Sometimes the ***bud*** of a new hydra rises from the side of the body. Spherical projections of the surface enclose the ovaries or the testes (Fig. 151).

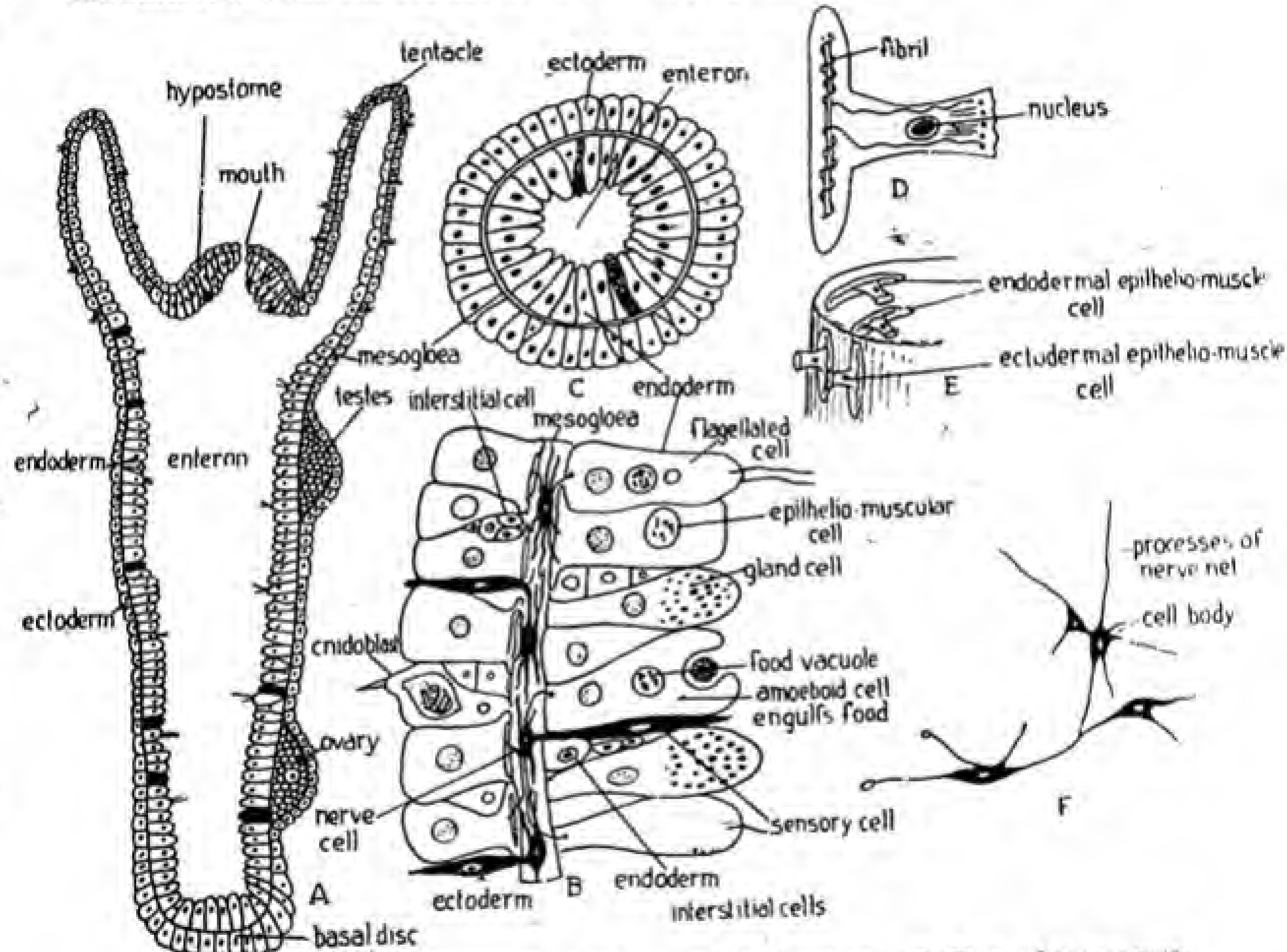


FIG. 144. Hydra. Structure. A. Longitudinal section. B. Part of transverse section greatly enlarged. C. Transverse section. The dark cells in A, B and C are sensory cells. D. Epithelio-muscular cell. E. Diagram illustrating the arrangement of the epithelio-muscular cells. F. Part of the nerve net. (*Partly from actual specimens and partly from various sources*).

The body wall consists of a thin external ***ectoderm*** and a thicker ***endoderm***, separated by a thin noncellular jelly-like ***mesogloea***. The mesogloea is an elastic skeleton secreted by the two layers of cells (Fig. 144).

Types of cells — The cells that compose the ectoderm and endoderm are not all alike. In the ectoderm occur 1. epithelio-muscular cells, 2. glandular cells, 3. interstitial cells, 4. cnidoblasts or stinging cells, 5. nerve cells and 6. sensory cells. The endoderm is composed of 1. epithelio-muscular cells, 2. gland cells, 3. sensory cells, 4. nerve cells and 5. interstitial cells.

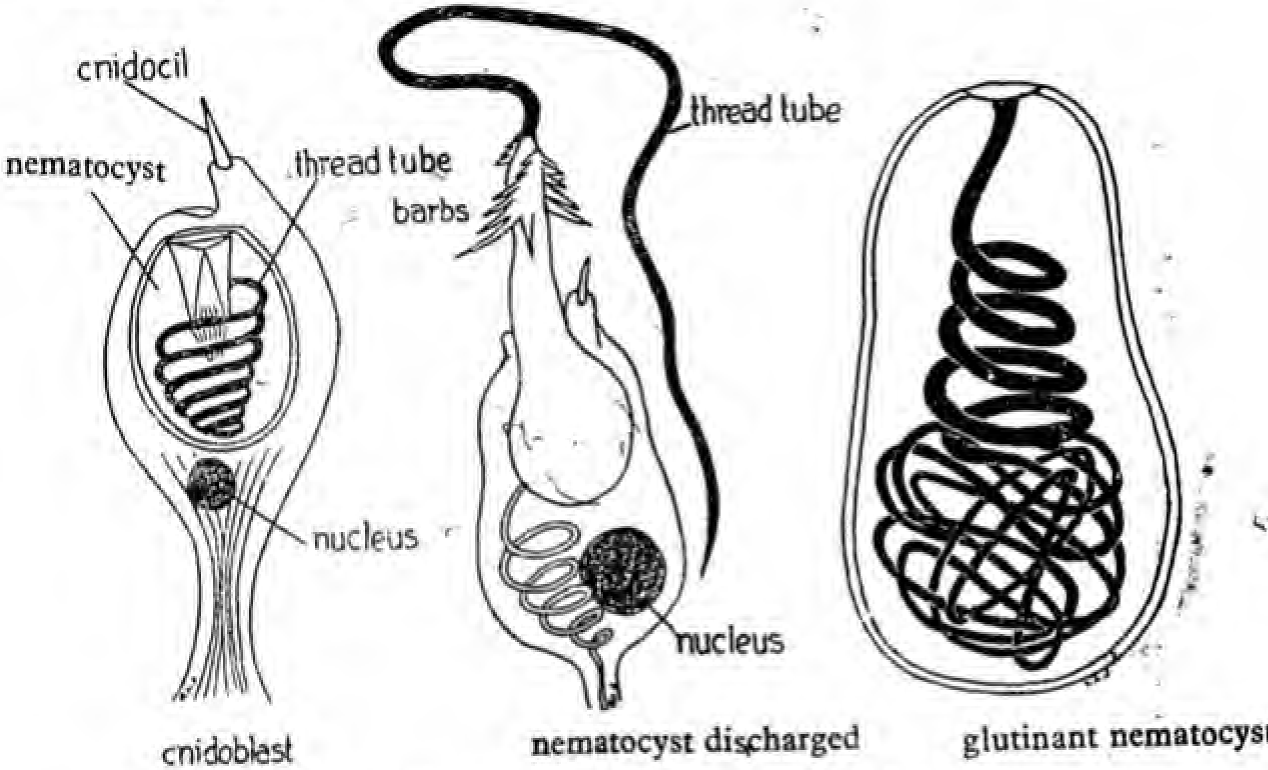


Fig. 145. Nematocysts of hydra. (*After Schulze*).

ECTODERMAL CELLS

1. ***Epithelio-muscular cells.***—The epithelio-muscular cells cover the general surface of the body. They are ⊥-shaped, with a swollen outer end and an elongate basal supporting lamella, in which are muscle fibrils. The cell secretes a cuticle. The basal lamellae with their fibrils run lengthwise against the mesogloea. They therefore act as longitudinal muscles and by contracting shorten the entire body.

2. ***Gland cells.***—Gland cells are present on the basal disc. They are columnar cells that secrete a sticky substance which helps the hydra in attaching itself to objects under water. These cells often produce bubbles of a gas. A few gland cells occur round the mouth also.

3. ***Interstitial cells.***—Between the large ectoderm cells there are small undifferentiated ***interstitial*** or ***subepithelial*** cells. These give rise to the cnidoblasts and the gonads.

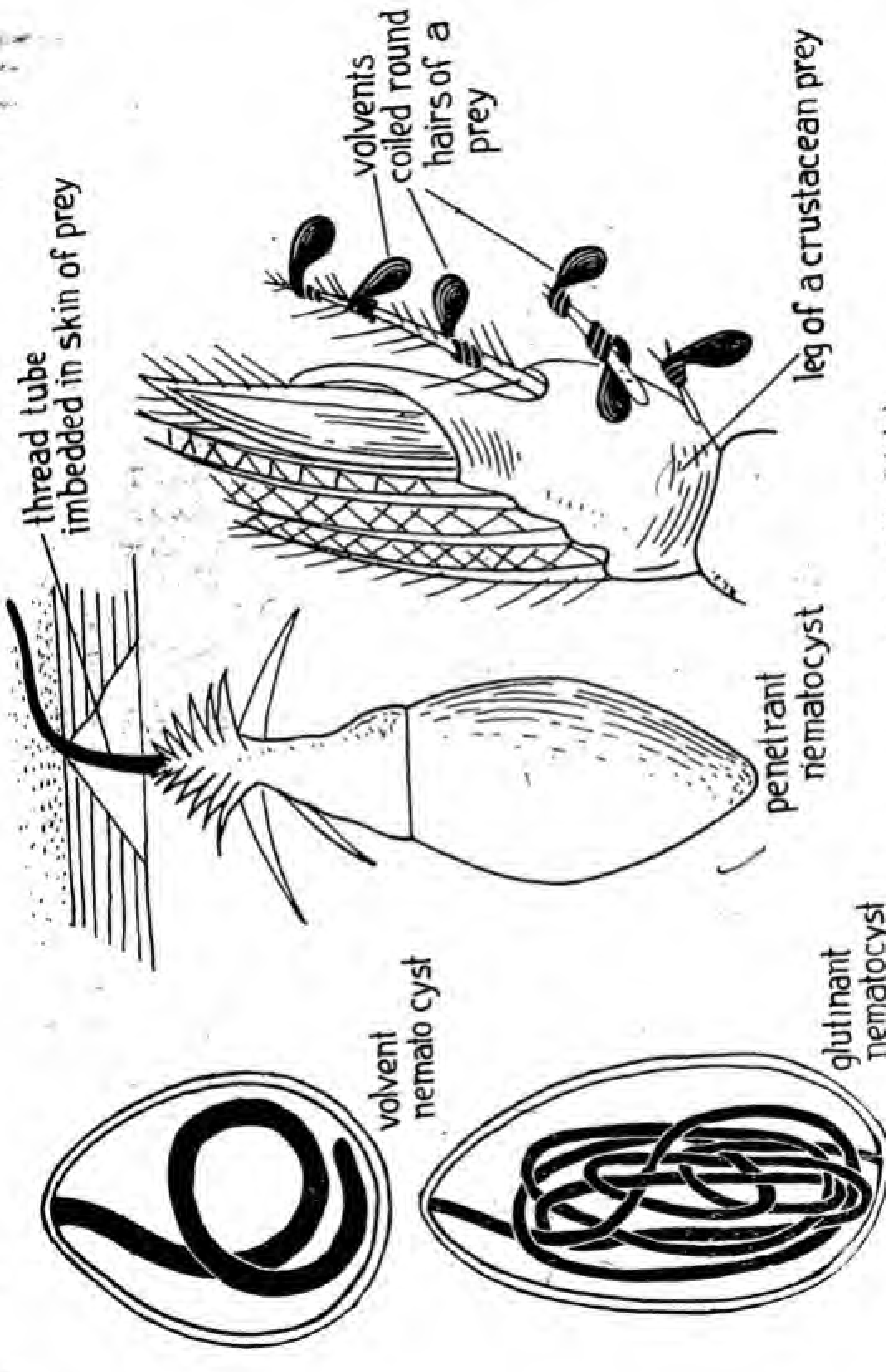


FIG. 146. Nematocysts of hydra. (*After Schulze*).

4. ***Cnidoblasts.***—The cnidoblasts (Figs. 145, 146) are organs of offence and defence. The cnidoblast or the nettle-cell is a specialized interstitial cell, modified for stinging and paralyzing a prey or a potential enemy. They are scattered throughout the ectoderm but are particularly abundant on the tentacles. The cnidoblast contains a ***nematocyst*** within. The nematocyst is a capsule filled with a poisonous fluid called ***hypnotoxin***. It contains a coiled ***thread-tube*** that may be instantaneously stretched out. On the exterior of the cnidoblast there is a ***cnidocil***, a trigger-like projection protruding on the surface of the body. It appears to be sensitive to the external stimuli which affect the cnidoblast. The nematocysts occur either singly or one large nematocyst is surrounded by several smaller ones to form a battery of stinging apparatus on the surface of the tentacles. This battery is indicated on the external surface by raised tubercles. The cnidoblasts have the power of migrating laterally from the body to the tentacles. They always arise on the body and migrate to the tentacles but none arise on the latter. After a discharge of the thread-tube, the cnidoblast cannot withdraw it and the nematocyst cannot be used again. It migrates to the enteron and is digested. A new cnidoblast is formed from the interstitial cells.

Cnidoblasts are ***independent effectors*** or structures which respond directly to stimuli and are not under the control of the nervous system.

There are four kinds of nematocysts: 1. penetrant, 2. volvent, 3. streptoline glutinant and 4. stereoline glutinant (Figs. 145, 146).

The ***penetrant nematocysts*** are large and spherical bodies with the thread-tube coiled transversely. The thread-tube has three long spines and three rows of thorns basally. When discharged, it pierces the skin of the prey and injects the ***hypnotoxin***. The effect of the discharge of the penetrant nematocyst is paralysis of the prey.

The ***volvent nematocysts*** are pear-shaped and relatively small. The thread-tube is short and coiled in a single loop. When discharged, the thread-tube coils tightly round the hairs of the victim (Fig. 146).

The ***streptoline glutinant*** nematocysts are as large as the volvent but have a longer thread-tube. The thread-tube is rolled in three or four transverse coils. It bears minute thorns. Upon discharge, it twists and coils.

The ***stereoline glutinant*** is the smallest nematocyst and has an unarmed thread-tube, which is discharged straight.

Nerve cells.—The ectoderm contains a network of nerve cells, which have long processes. These processes are not however differentiated into dendrons and axons as in the case of the nerve cell of the frog. The

processes of the different nerve cells are not simply in contact as in synapse of the frog but are actually continuous one with the other, so as to form a

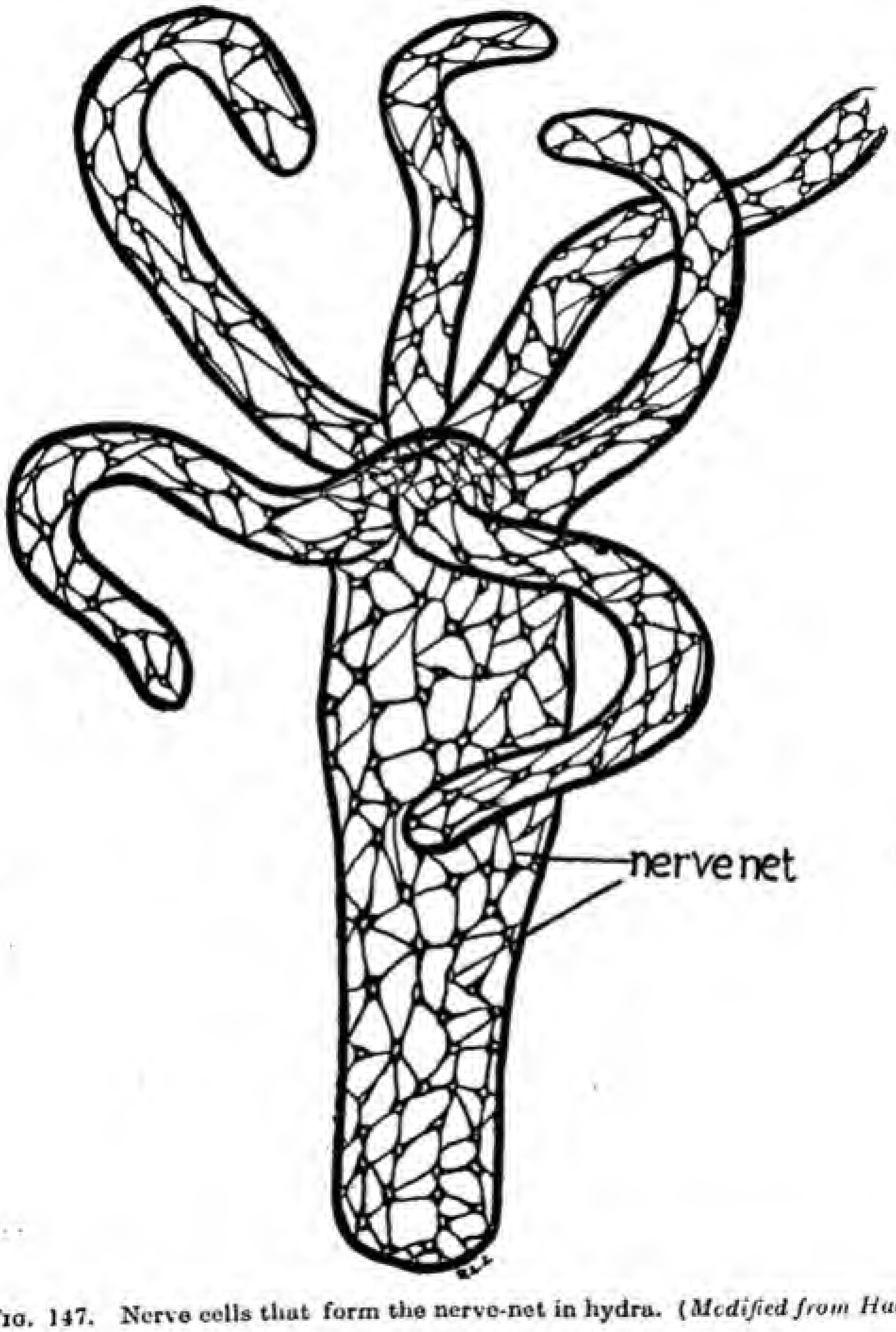


FIG. 147. Nerve cells that form the nerve-net in hydra. (*Modified from Hadzi*).

nerve-net (Fig. 147). A nerve cell is associated with each cnidoblast and with sensory cells. The nerve cells are also connected with muscle fibres.

Sensory cells.—The sensory cells are connected at the base with nerve cells. There are four kinds of sensory cells with slender tips. They are specially abundant on the tentacles and near the mouth.

The interconnected nerve cells, sensory cells and muscle fibrils constitute the ***sensory-neuro-motor*** mechanism of the hydra. The sensory cells are the receptors that receive stimuli, the nerve cells conduct impulses and the muscle fibrils are the effectors that respond to the stimuli. The mechanism co-ordinates the movement of the body and of the tentacles.

The gonads are temporary structures produced by the interstitial cells in the ectoderm. These are further considered under Reproduction.

ENDODERMAL CELLS

The epithelio-muscular cells of the endoderm differ from those of the ectoderm. The contractile fibrils are attached to the mesogloea transversely to the axis of the body (Fig. 144). They therefore act as circular muscles and by their contraction reduce the diameter of the body but elongate it. The fibrils at the bases of the tentacles and near the mouth act as sphincters that close these openings. The endoderm cells bear one or two flagella and often put out pseudopodia. There are no muscle cells in the tentacles, so that the tentacles are extended by fluid pressure alone.

Gland cells of the endoderm are relatively large and secrete the digestive enzymes. A few interstitial cells occur in the endoderm. Sensory and nerve cells of the endoderm are relatively few. There is no net-work of nerve cells in the endoderm. The scattered nerve cells of the endoderm are not also connected to the ectodermal network.

The various cells which have been described thus far constitute the ***somatic cells*** of the hydra. The gonads form the ***germ cells.*** Each of the somatic cells is specialized for a particular function but the cells do not form tissues as in the frog. There are therefore no true organs in hydra. The tentacle may perhaps be called an organ.

Motion and locomotion.—The hydra performs (Fig. 148) various kinds of movements. It can shorten its body to about a sphere or stretch it fully (Fig. 149). It can bend the body in all sorts of ways. The tentacles can be shortened or extended, curved and used in holding a prey.

Locomotion (Fig. 148) is effected in several ways. The simplest method of locomotion is gliding on the substratum due to the amoeboid movement of the cells of the basal disc. Very often a hydra uses a bubble of gas secreted by the gland cells of the disc as a float to rise to the surface of the water and to be passively wafted along by water currents (Fig. 149). They also float free, with the tentacles fully extended, mouth

either above or below. The usual and the most rapid method of locomotion is the so-called "walking" or somersaulting of the hydra (Fig. 148).

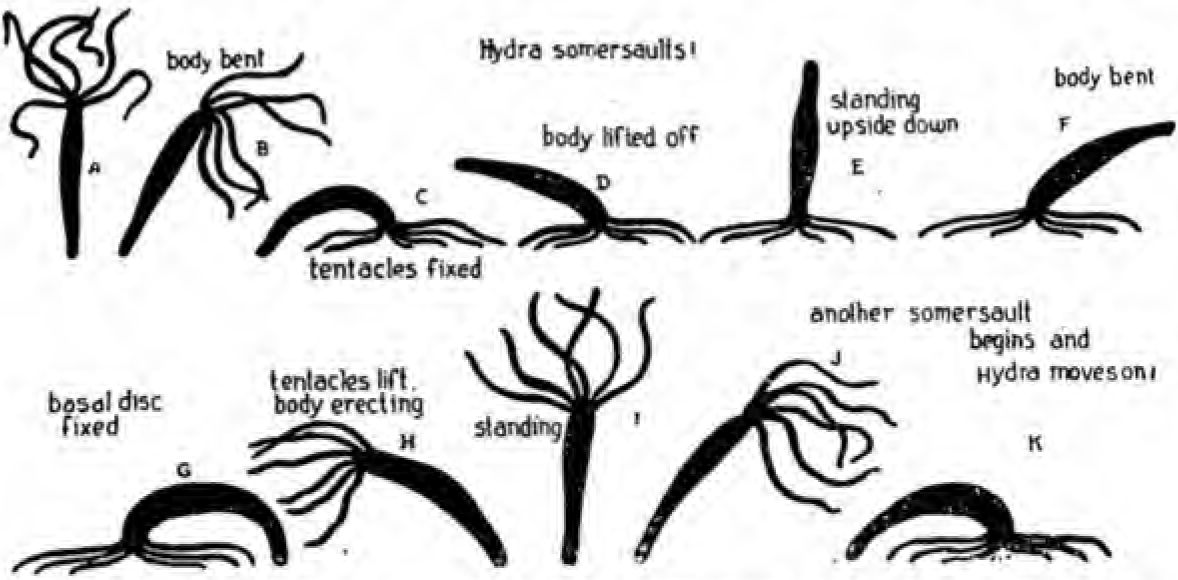


Fig. 148. Hydra in locomotion. A-K, stages in the "walking" or somersaulting by hydra.

This somersaulting resembles the looping action of a geometrid caterpillar. The hydra bends the body down to the substratum on the side it wants to go. The tentacles are fully extended. Their tips are attached to the ground by the glutinant nematocysts. The basal disc is released from the ground. The whole body is then dragged forward, thus making a somersault. It is

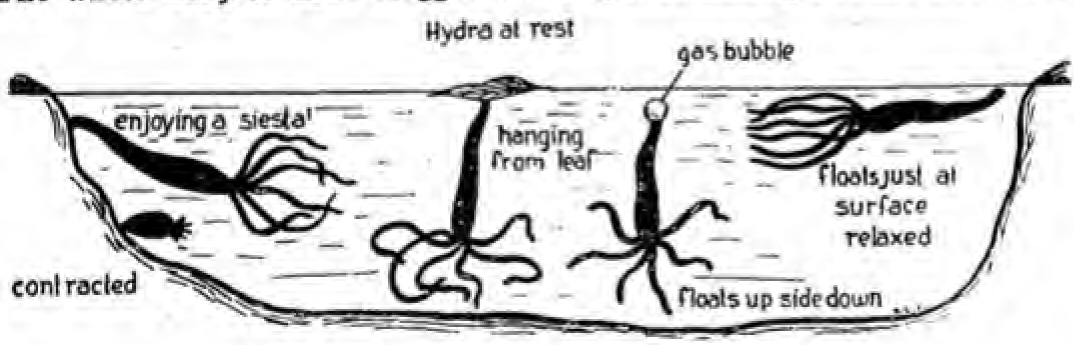


Fig. 149. Resting attitudes of hydra.

then laid flat on the other side and the basal disc now fixed. The tentacles are wrenched away free and the animal regains the upright posture. Once again the body is bent and the whole series of movements repeated. The hydra can in this way bridge itself away across any gap.

Nutrition.—Hydra is a carnivorous animal. Its food consists mainly of small Crustacea, aquatic larvae of insects (for example bloodworms

or the larvae of gnats), eggs of fish and even very young fishes, small worms and other small animals of a convenient size. A hydra sometimes seizes more than it can swallow and in the attempt to do the impossible it often turns its body inside out.

A hydra does not really hunt for its food. When hungry it simply stands on its basal disc, with the tentacles extended and waving gently (Fig. 150). A small prey, as for example a *Cyclops*, accidentally bumps into one of the tentacles and the unlucky victim is gone. It is suddenly bombarded with dozens of the nematocysts. Its skin is riddled through and through by the penetrant nematocysts, which inject the hypnotoxin into these punctures. The luckless cyclops is paralyzed. The volvent nematocysts wrap round any hairs or spines on the legs of the victim and the glutinant nematocysts stick to its surface (Fig. 146). The poor prey is safely secured. The tentacle bends round the paralyzed victim and other tentacles also may often help to secure the prey by discharging their nematocysts and by coiling round. The food is gradually conveyed to the mouth, which gapes open greedily to receive it. The prey is gulped whole by contractile movements of the hypostome. The swallowing is also facilitated by the mucus secreted by the gland cells.

The food is digested partly in the enteron. The endodermal gland cells pour out their secretions containing protein and fat splitting enzymes. The body wall contracts and expands and thus aids the thorough mixing of the food with the digestive fluid. The lashing of the flagella of the endoderm also helps in this mixing-up. The food becomes disintegrated and the soft parts gradually dissolve away to form a thick liquid in which are suspended numerous fragments. The dissolved parts are absorbed by the endoderm. The fragments are ***engulfed*** by the pseudopodial processes of the endoderm cells and food vacuoles are formed in them. The digestion is completed within the cells. The process of digestion of food in the hydra is thus carried out both in the enteric cavity, that is outside the cells, as in all Metazoa like the frog and also within the endodermal cells as in the Protozoa. The hydra thus combines the ***extracellular*** digestion of the Metazoa and ***intracellular*** digestion of the Protozoa. The absorbed food is either used immediately or stored up as glycogen. The undigested part of the food is egested through the mouth, which thus functions as the anus also.

Respiration and excretion. – Respiration in the hydra is by diffusion of the oxygen dissolved in the water. The excretory products directly diffuse away from the cells.

Within the green hydra, *Chlorohydra viridissima*, lives the green alga *Zoochlorella*. The hydra utilizes for its own respiration the oxygen liberated during the photosynthesis of this green plant. The plant also benefits by utilizing the carbon dioxide excreted by the hydra.

Regeneration and grafting.—A hydra has extraordinary powers of regenerating lost parts. If a hydra is cut into two or more pieces, each of the pieces will grow into a complete hydra! A cut tentacle will grow the rest of the body and become in due time a complete hydra. If a hydra is split longitudinally near the hypostome, each half becomes complete and thus gives rise to a double-headed hydra. Two hydras can also be grafted together.

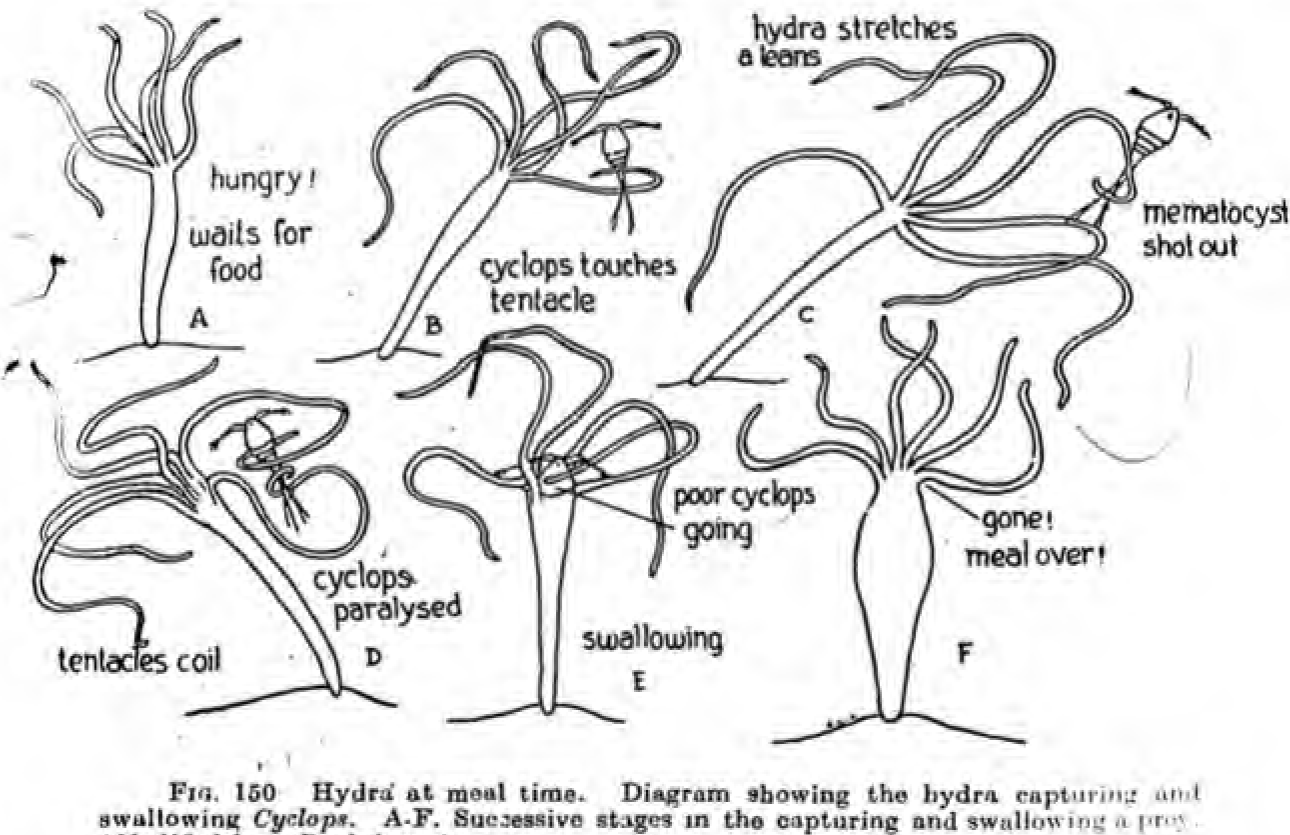


FIG. 150 Hydra at meal time. Diagram showing the hydra capturing and swallowing *Cyclops*. A-F. Successive stages in the capturing and swallowing a prey. (*Modified from Buchsbaum*).

Reproduction.—The hydra reproduces by 1. budding, 2. fission and 3. sexual method.

Budding.—A hydra ***bud*** arises as a bulge of the body wall about the middle of the body (Figs. 140, 151). This enlarges and elongates and its cavity communicates with the enteron. Blunt tentacles grow at the free end of the bud, where a mouth and hypostome also develop. The bud is now constricted and separated at the base from the parent hydra. It becomes

an independent hydra, which also reproduces by buds in its turn. Budding is very common at all times of the year.

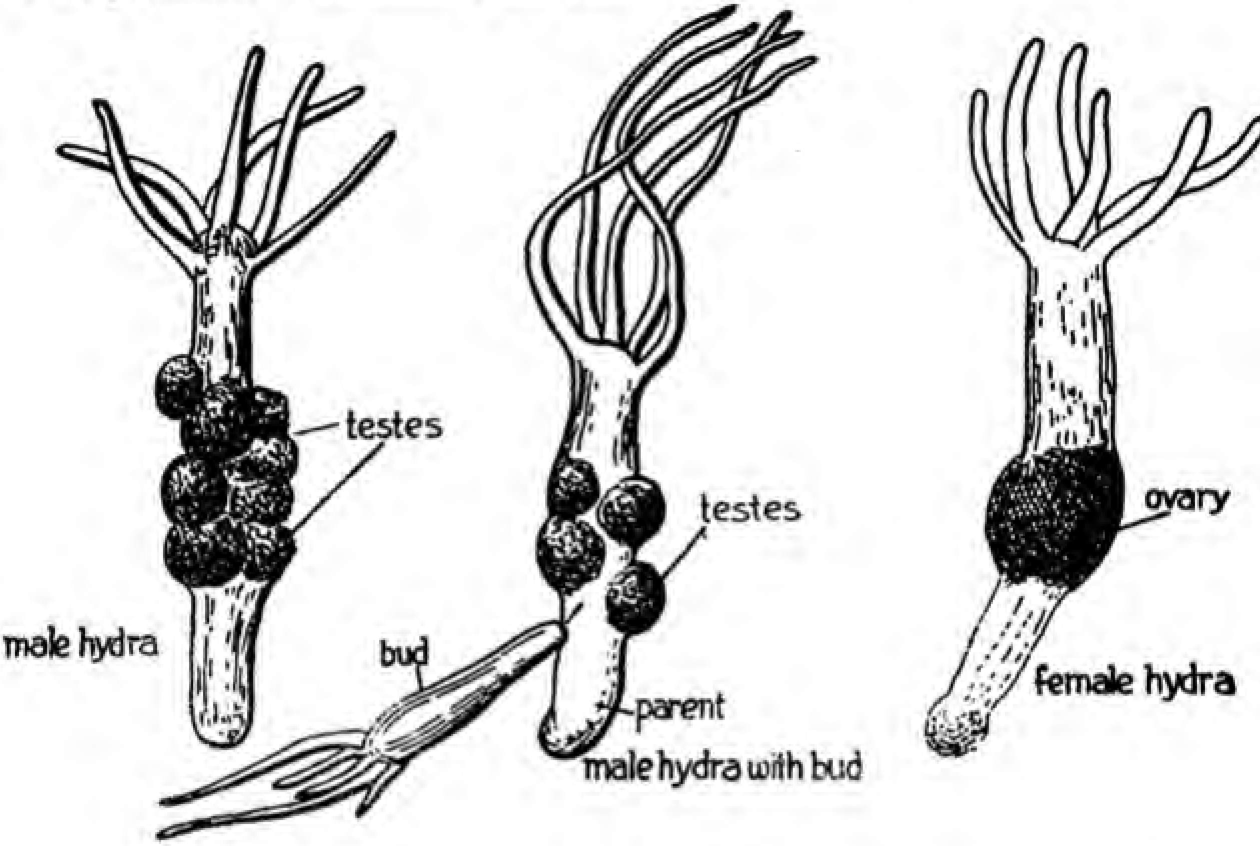


Fig. 151. Reproduction in hydra.

Fission.—Reproduction by fission is rare in nature. The hydra splits into two lengthwise or transversely and each part becomes a complete hydra. Closely associated with this method of reproduction is the power of regeneration of lost parts.

Sexual reproduction.—Some hydras are hermaphrodites but most others are ***dioecious***, *i.e.*, are either males or females. Ovaries and testes are temporary structures produced by the interstitial cells of the ectoderm on the surface of the body and are the only means of distinguishing the sexes (Fig. 151).

A male hydra possesses several testes as blunt conical outgrowths on the surface. They are usually located on the distal half of the body. Each testis contains a number of elongate cysts. The interstitial cell that is destined to produce the sperms is called the ***spermatogonium***. Several spermatogonia are enclosed by the ectodermal epithelio-muscular cells. The spermatogonia repeatedly divide and give rise to ***spermatocytes***. Each spermatocyte divides twice and thus produces four ***spermatids***. Each spermatid grows a tail and becomes a ***sperm***.

In the female hydra (Fig. 151, 152), there is usually a single ovary. It is located at the middle of the body. It arises as an ectodermal bulge enclosing many ***oogonia.*** The oogonia are derived by repeated division of an interstitial cell. Only one of these oogonia becomes an ***oocyte*** : this oogonium enlarges, develops pseudopodia and begins to engulf the rest of

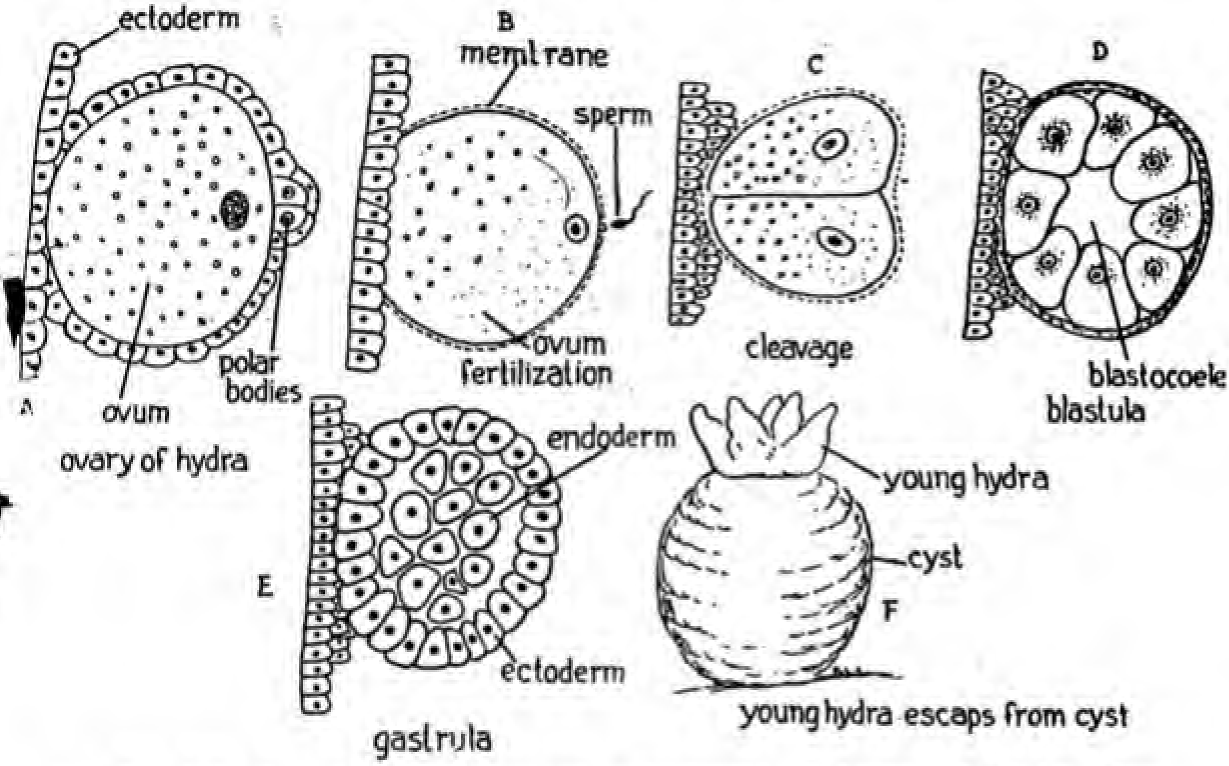


FIG. 152. Sexual reproduction and development in hydra. (*Modified from Tannreuther*).

the oogonia which thus form its food. When mature, it is an oocyte. The oocyte undergoes maturation division by throwing off polar bodies and thus becomes the ***ovum***, containing the haploid number of chromosomes, six to twelve. The epithelial covering of the ovary becomes weak, breaks away and leaves the ovum exposed.

Development. – (Fig. 152) The ovum is fertilized on the parent body. The sperm is discharged into the water where it swims about actively by the lashing movement of its tail and when it finds an exposed ovum, enters and thus fertilizes it. The early development of the ovum is also completed on the parent.

The first two segmentations are meridional and at right angles to each other. These are followed by equatorial cleavage giving rise to eight blastomeres, enclosing a blastocoele. When the blastulation is ended,

a cyst is secreted by the blastoderm all round. Gastrulation takes place by ***multipolar immigration*** : the blastomeres divide tangentially. The outer ends divide off into the ectoderm and the inner ends into the endoderm. Some of the blastomeres bodily migrate deeper to form the endoderm. The cyst with the embryo now drops off into the water from the parent and undergoes a period of rest. The enteric cavity now develops and again after a short period of rest, a young hydra, complete with tentacles, hatches out.

Natural enemies.—The hydra is attacked by a minute worm in Europe. In India, the bloodworm, on which the hydra itself feeds, turns the table and devours smaller hydras ! The larvae of *Chironomus* gnats contain haemoglobin and are therefore called bloodworms. They are aquatic and often build cases of sand, which they web together by silken threads. When the larva finds a hydra, it begins to web the hydra by its silk, taking care not to get foul with its tentacles. When the hydra's body is almost completely enclosed, the tentacles are gradually spun down and then the larva lunches off the body of the imprisoned hydra. A number of Protozoa are often associated with the hydra and some of them are undoubtedly parasitic on it.

Symbiosis.—The green alga *Zoochlorella* which lives within the green hydra is not a parasite. It is not an enemy of the hydra. It benefits the hydra by taking away the excretory product, carbon dioxide, from the hydra's respiration and also gives oxygen to it for respiration. The alga is also benefited by getting shelter, in addition to water, minerals, carbon dioxide, etc. from the body of the hydra. The association of the alga and the hydra is thus mutually beneficial. It is a sort of friendly living together, which is called ***symbiosis***.

Behaviour.—The hydra reacts to various stimuli. A hungry hydra reacts more vigorously than a full-fed one. It is easily affected by rise of temperature.

2. OBELIA

General features and systematic position.—Obelia is a colonial marine hydroid. It occurs as a delicate light-brown moss-like growth on submerged rocks, wooden piles of piers and shells in shallow waters of the sea coast. The colony arises by budding from a single hydra-like polyp. The buds do not separate but remain connected with the parent stock and in their turn go on repeatedly budding, all the buds remaining connected, so that a plant-like colony results. The polyps that comprise the colony of *Obelia* are united by stems called ***hydrocauli***,

which are rooted in the substratum by ***hydrorhiza***. There are several species of *Obelia* but *Obelia geniculata* is usually chosen as the type. Its systematic position is given below :

Phylum COELENTERATA
Class HYDROZOA
Order *LEPTOLINAE*
Suborder LEPTOMEDUSAE
Family Campanulariidae
Genus *Obelia*
Species *geniculata.*

Structure. – An Obelia colony is ***polymorphic***, (Fig. 153) *i.e.*, it has many forms. It comprises three types of individuals: 1. ***hydranth***, 2. ***gonangium*** and 3. ***medusa***. The hydrocauli that support them is composed of an external ***perisarc*** and an internal ***coenosarc***. The perisarc is a transparent non-cellular covering of chitin, ringed at the joints. The coenosarc is hollow and comprises the ectoderm, mesogloea and endoderm. It does not fill up the cavity of the perisarc but is attached to it at intervals by strands of ectodermal cells.

Hydranths (Fig. 154) are the feeding polyps, very much resembling the hydra. A hydranth is enclosed in a ***hydrotheca***, which is merely an expanded part of the perisarc. The wall of the hydranth is composed of ectoderm, mesogloea and endoderm as in the hydra and is really a branch of the coenosarc of the hydrocauli. Each hydranth has numerous tentacles, which are used in capturing food much as in hydra. The tentacles of the obelia differ however from those of the hydra in being completely solid. The endoderm fills the interior, so that the tentacle is not hollow as in hydra. There are numerous nematocysts on the tentacles and these function in the same manner as those of hydra. Within the circlet of tentacles is a very large hypostome, which is hollowed out to form a spacious ***pre-oral*** cavity. The true mouth is at the bottom of this cavity. The hydranths are solely concerned with the capturing of food not only for themselves but for the entire colony and they have nothing to do with sexual reproduction.

Gonangium. – The gonangium comprises an urn-shaped ***gonotheca***, enclosing a tubular ***blastostyle***. The gonotheca is a continuation of the perisarc and is open at the tip. The blastostyle is a modified hydranth, without tentacles or mouth and incapable of capturing food for themselves. They are specialized as reproductive members of the colony. The blastostyle bears a number of ***medusa buds***. The medusa buds break

off and escape as ***medusae*** or jellyfishes from the gonangium by way of the terminal opening in the gonotheca.

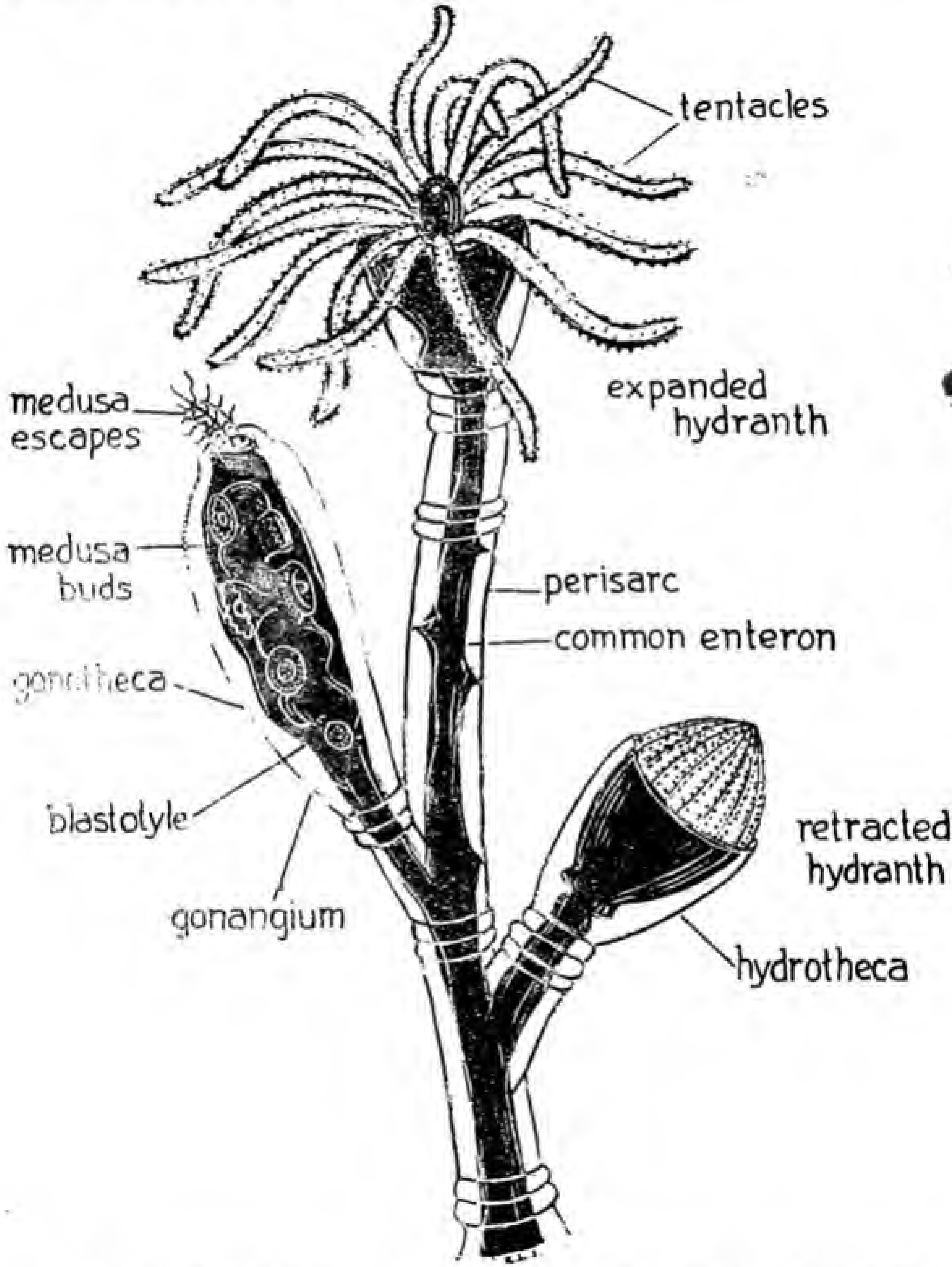


FIG. 153. Part of *Obelia* colony showing three polyps. The medusae escape from the gonangium.

Medusa.—The medusa is an umbrella-shaped transparent jellyfish. The bulk of the medusa umbrella is composed of thick mesogloea. The convex outer surface of the umbrella is called ***ex-umbrella*** and

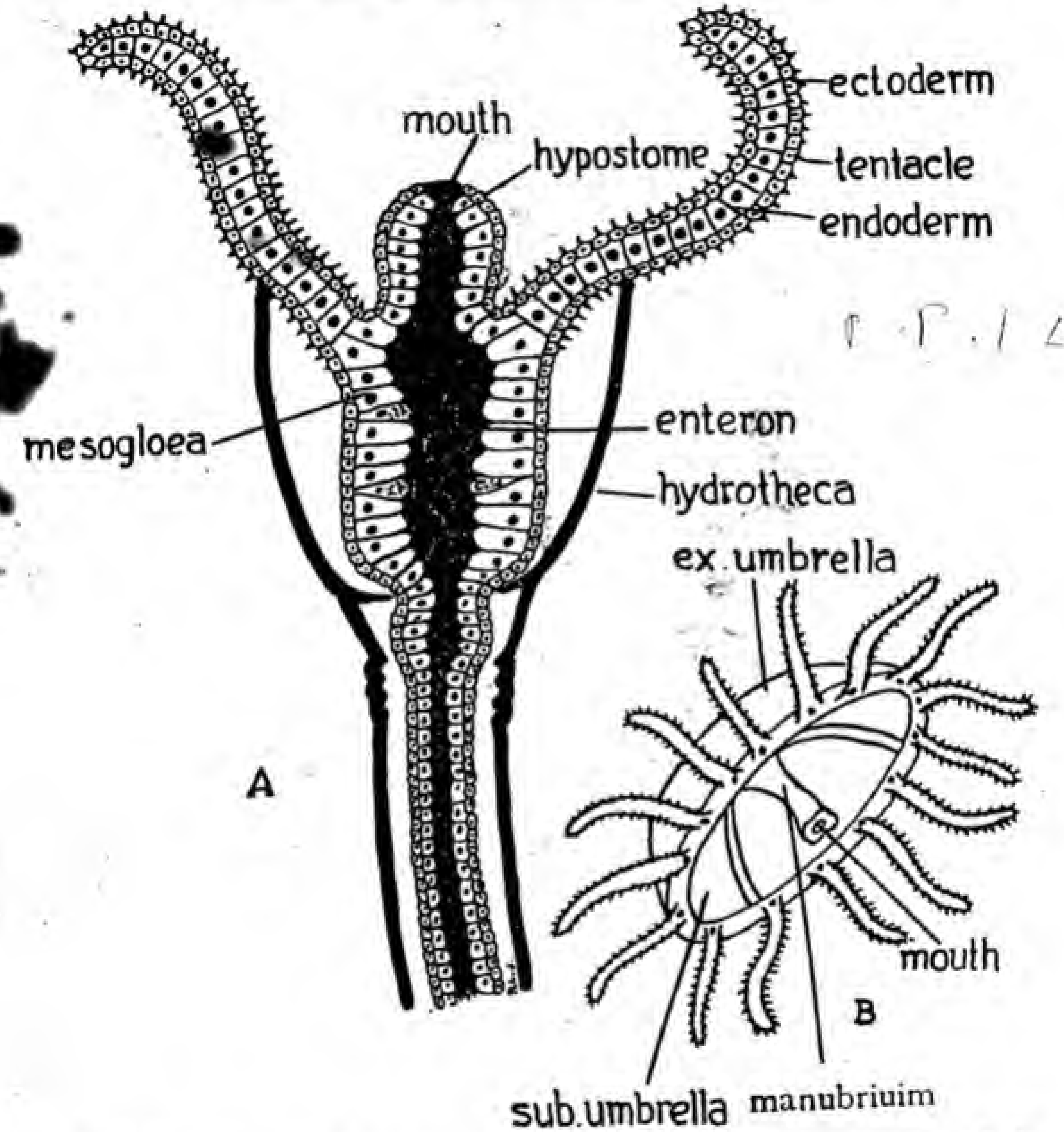


FIG 154. Structure of *Obelia*. A. Feeding hydranth that is essentially a hydra, enclosed in a test and with solid tentacles. B. Medusa that is essentially an inverted hydra and leads a free-swimming life. It is the reproductive polyp.

the concave lower surface forms the ***sub-umbrella***. In the middle of the sub-umbrella is the short handle of the umbrella called ***manubrium***. The margin of the umbrella is fringed with a number of tentacles. A

mouth opens at the free end of the manubrium and leads into the enteron inside. The enteron gives off four ***radial canals*** in the dome of the umbrella. The radial canals extend to the ***circular canal*** within the margin of the umbrella The tentacle at the ends of the radial canals is swollen at the base and has a patch of pigmented ectodermal cells sensitive to light : this is the ***ocellus***. Between two radial canals a tentacle has an ocellus and also a ***statocyst***. The statocyst is a hollow vesicle with calcareous crystals. The cells that line [illegible] cavity of the vesicle have fine hairs projecting inside. The statocyst is an organ of equilibrium.

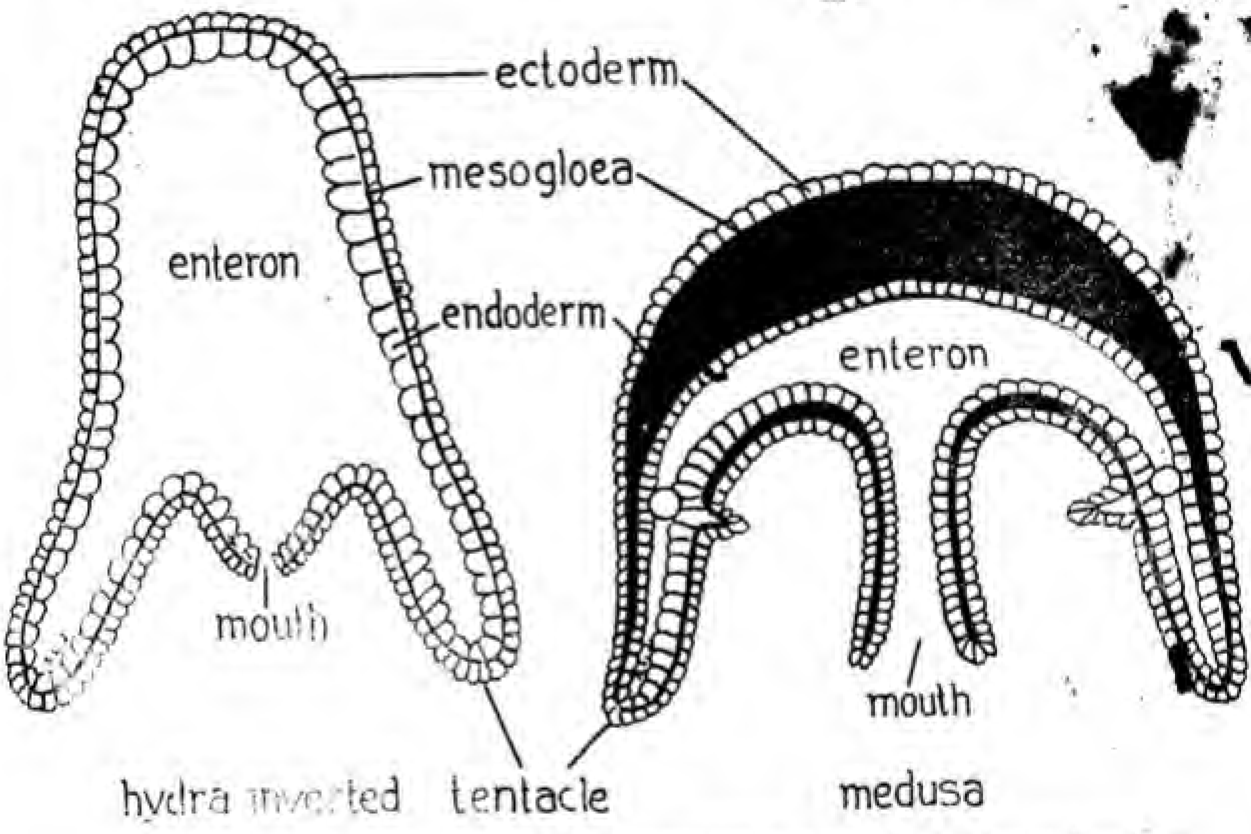


FIG. [illegible] illustrating the comparison in structure of polyp and medusa. In the [illegible] the mesogloea is meagre but in a medusa it is considerable. They are both [illegible] the same plan.

On escape from the gonotheca, the medusae float away and lead a free life. They capture food and grow. Although the feeding hydranth and the medusa differ markedly, their basic structure is essentially the same as that of a hydra.

Reproduction and development—The medusae are the reproductive members of the obelia colony. The sexes are separate. The gonads (Fig. 156) develop on each of the four radial canals as finger-like

projections of the body wall. They hang down from the sub-umbrella when ripe.

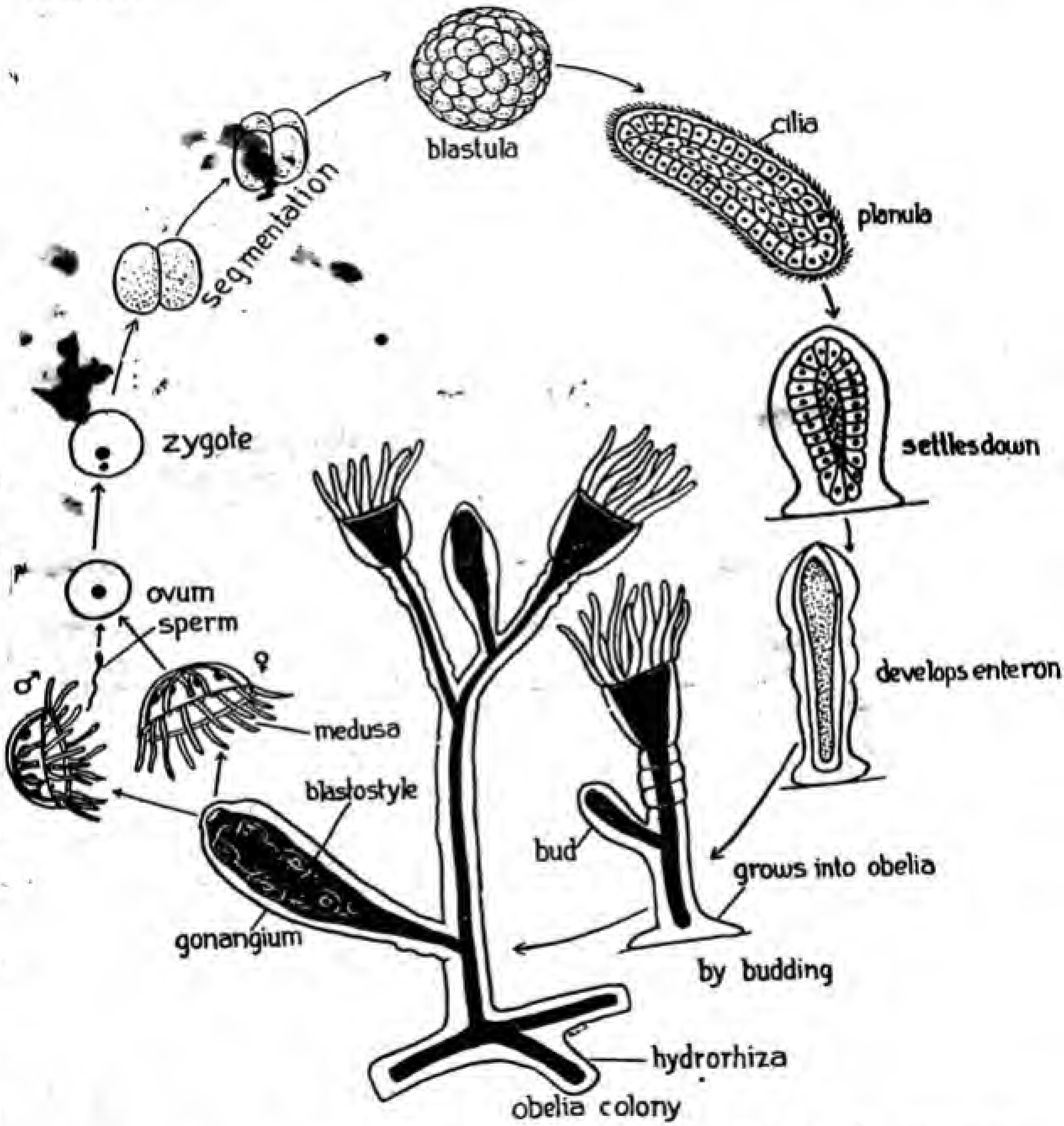


FIG. 156. Life-cycle of *Obelia*, a colonial marine hydroid, showing the polymorphic colony, medusae, developing embryo and hydra-like founder of the colony. The colony consists of hydranths and gonangia, arising asexually by budding from branched stems. The free medusae bud off from the gonangia and produce the ova and sperms. The zygote develops into a free-swimming planula larva, that settles down and develops into the obelia colony.

The oogonia and spermatogonia arise in the ectoderm of the manubrium. They migrate into the endoderm and undergo maturation division. Ultimately they reach the ovaries or testes.

The ovaries and the testes burst open and release the ova and sperm into the water. The ova are fertilized in the water (Fig. 156). The zygote undergoes cleavage and a blastula is formed as in hydra. A solid gastrula then arises. The external layer of cells represents the ectoderm and the solid inner mass of cells the endoderm. The gastrula then elongates into an embryo, somewhat broader at one end. The ectoderm develops cilia and the embryo now becomes a free-swimming larva called ***planula***. The planula swims about for some time by ciliary action. An enteron develops within the solid endoderm. The planula now settles down on some suitable object by its broader end, loses the cilia and grows into a hydra-like animal. The base by which the planula is fixed becomes broadened but soon elongates and branches profusely to give rise to the hydrorhiza. The free end becomes swollen and a mouth and several tentacles develop at this end. The ectoderm secretes a perisarc. This hydra-like founder of the future obelia colony grows larger, puts out buds repeatedly and thus ultimately gives rise to the colony.

There is thus an ***alternation of generations*** and forms—hydranths and medusae— in the life-cycle of obelia. After the medusae are formed the obelia colony dies; after the ova and sperms are produced the medusae die.

Comparison with hydra.—Obelia may be considered as a hydra which has budded several times, but all the buds remaining connected to the parent. Obelia differs from hydra in having a theca – perisarc and hydrotheca. The hydranths have more tentacles than hydra. The tentacles of the obelia are not hollow but solid. The hypostome is enormous. Hydra has the power of locomotion but an obelia colony is fixed. Hydra carries on all the functions of life, including sexual reproduction but the hydranths are not capable of sexual reproduction. Despite these differences, the hydra and obelia have the same body-plan and an obelia colony arises from a hydra-like polyp.

3. AURELIA

AURELIA is a common jellyfish of coastal waters. Jellyfishes differ from hydra and obelia in several respects. In the jellyfishes the medusa stage is often several feet in diameter. An enormous gelatinous mesogloea constitutes the bulk of the body of a jellyfish.

Systematic position.—The common jellyfish *Aurelia* belongs to :
Phylum COELENTERATA
Class SCYPHOZOA
Order DISCOMEDUSAE
Genus *Aurelia.*

Structure.—The body of the jellyfish is a broad, shallow cup, slightly convex on the upper or ***aboral*** and concave on the lower or ***oral*** surface. It is essentially an inverted cup that is fringed by a row of ***marginal tentacles.*** The marginal tentacles are interspaced at regular intervals by eight groups of ***sense organs*** between paired ***lappets.***

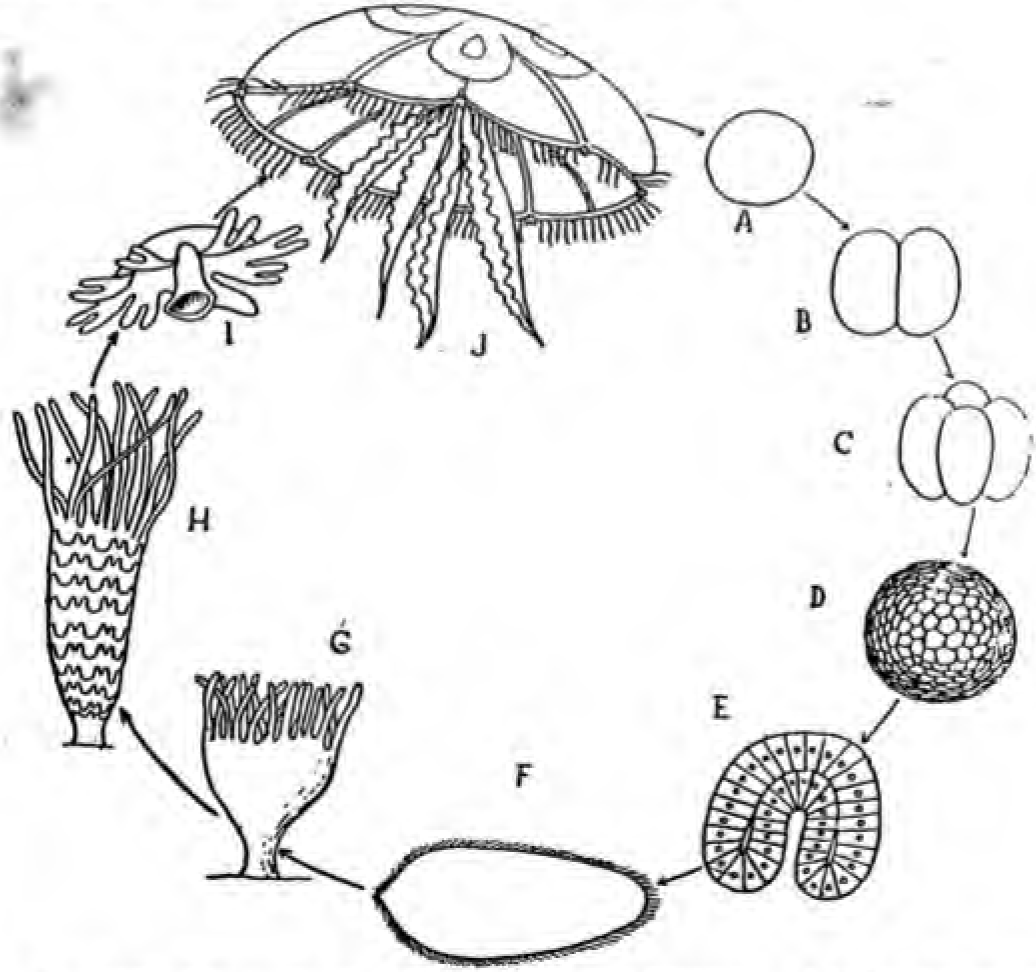


FIG. 157. Life-cycle of *Aurelia*, a common jellyfish. A-C. Cleavage : zygote 2-cell and 4-cell stages. D. Blastula. E. Gastula in section. F. Ciliated planula larva—free-swimming. G. Settles down to the sea bottom and becomes a polyp, with tentacles. H. Strobilation I. Ephyra. J. Adult jellyfish. (*Modified partly from, Korschelt-Heider and from Hatschek*).

The ***mouth*** is situated on a short ***manubrium*** in the centre of the oral surface, between four ***oral arms.*** These latter are grooved and

also bear ***nematocysts*** on the margins. A short oesophagus leads to the ***enteron*** that has four ***gastric pouches.*** Slender ***gastric filaments*** within the gastric pouches bear nematocysts. ***Radial canals*** extend through the mesogloea from the pouches to the ***ring canal*** in the rim of the inverted cup. Four ***gonads*** occur, one in each of the gastric pouches. The ***nerve net*** is well developed marginally. Each sense organ comprises a pigmented ***eyespot***, a ***statocyst*** with calcareous granules and ***sense pits*** probably of chemotropic function. The body wall comprises an ectoderm, an enormous mesogloea and an endoderm.

Life history.—The sexes are separate. The sperms from the gonads of the male pass out by the mouth and into the gut of the female, where fertilization takes place. The zygote becomes lodged on the oral lobes of the female and develops into a ciliated ***planula*** larva (Fig. 157). The planula escapes from the parent and after leading a short free-swimming life, settles down to the sea bottom. It loses the cilia and grows into a ***polyp.*** The polyp has a basal disc, mouth and tentacles; it is called ***scyphistoma.*** The scyphistoma grows in size and produces lateral buds that become detached and grow into independent polyps like hydra. In autumn and winter however another kind of budding called ***strobilation*** takes place. The scyphistoma undergoes transverse fission and gives rise to a series of cup-like structures piled one above the other. These cup-like structures separate off one by one and become the ***ephyrae*** larvae. The ephyrae now invert and gradually grow into the adult jellyfish.

RESUMÉ

I. Coelenterata

1. The Coelenterata are the simplest metazoa. They may be described as merely alimentary canals, enclosed by a skin.
2. They are all aquatic and comprise the hydroid polyps, medusae, jellyfishes, sea-anemones and corals.
3. The Coelenterata are divided into Hydrozoa, Scyphozoa and Anthozoa.

II. Hydra

4. The hydra is a fresh-water polyp that is common in tanks rich in vegetation.
5. Its body is a slender tube that is closed at one end and has the mouth on a hypostome at the other. Tentacles surround the mouth.
6. The body wall comprises the ectoderm separated by a mesogloea from the endoderm. The two layers include epithelio-muscular, glandular, interstitial cnidoblast, nerve and sensory cells.
7. The nematocysts are specialized structures of offence and defence. They sting and paralyze the prey.
8. The ectoderm has a nerve-net.
9. Locomotion is by looping movements of the body.
10. Digestion is both intra and extra-cellular.
11. Hydra reproduces by fission, budding or by ova and sperms.

III. **Obelia**

12. The obelia is a polymorphic colony composed of hydranths, gonangia and medusae.
13. It is fixed by hydrorhizae and is enclosed in a loose theca.
14. The medusae escape from the colony and develop the gonads.
15. Fertilization takes place in water and the planula larva settles down to grow and branch into the obelia colony.

IV. **Aurelia**

16. Aurelia is a common jellyfish, that is essentially a huge medusa with an enormous mesogloea.
17. There is an alternation of generations, in the course of which ova and sperms produce a ciliated planula larva that settles down and grows into a polyp. The polyp reproduces asexually by two types of budding: lateral buds separate and become polyps once again. Strobilation produces the ephyrae larvae that grow into the jellyfish.

CHAPTER IX

PLATYHELMINTHES

Platyhelminthes The PLATYHELMINTHES or the "flatworms" are the lowest triploblastic animals with bilaterally symmetrical body. They have an anterior and a posterior end. The body is not segmented. The coelom is filled up with packing-cells called ***parenchyma***. They have no skeletal, circulatory or respiratory systems. An alimentary canal is usually present or wholly lacking. The excretory system is well developed and consists of branched tubules ending in a funnel-shaped cup. The nervous system comprises two or more longitudinal nerve cords connected to a brain in the anterior end of the body. The flatworms are free living animals like planarians or are parasitic forms like the tapeworms.

Characters.—The Platyhelminthes are recognized by the following characters :

1. Triploblastic, bilaterally symmetrical, flattened, unsegmented.
2. Epidermis ciliated with cuticle or with hooks.
3. Digestive tract branched, without anus or wholly absent in some.
4. No coelom ; the body cavity filled by parenchyma.
5. No skeletal, circulatory or respiratory organs.
6. Excretory organs branched and with numerous flame cells.
7. Nervous system consists of a pair of anterior ganglia or nerve ring, with 1—3 longitudinal nerve cords.
8. Monoecious; gonads with ducts.
9. Fertilization internal. Development direct or with metamorphosis and two or more larval forms.
10. Free living or parasitic and often with alternate hosts.

The Platyhelminthes show many advances over the Coelenterata: 1. bilateral symmetry, 2. nervous system of brain and nerve cords, 3. presence of mesoderm, 4. presence of muscles and 5. permanent gonads.

Classification. Nearly 7000 species of flatworms are known. They are classified as follows :

Phylum PLATYHELMINTHES

Class 1. *TURBELLARIA*. Free living ; with ciliated epidermis. Example : *Planaria*.

Class 2. *TREMATODA*. Flukes. Parasitic, with suckers for attachment. Example : *Fasciola*.

Class 3. *CESTODA*. Tapeworms. Parasitic, without alimentary canal. Example : *Taenia solium*.

TREMATODA

The Trematoda or "flukes" are exclusively parasitic flatworms that live either as ectoparasites or as endoparasites of various animals. The body is protected by a cuticle. The gut has two main lateral branches. The ectoparasites develop directly from the ova but the endoparasites undergo metamorphosis and also change to one or more intermediate hosts. Most flukes are hermaphroditic; some are unisexual.

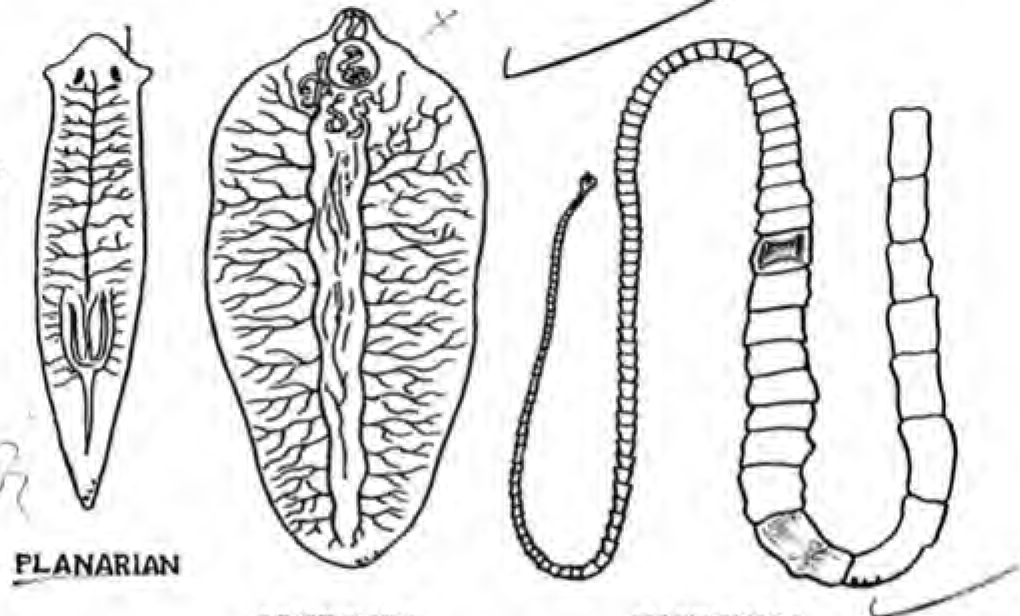


FIG 158. Phylum Platyhelminthes. Classes: Turbellaria, Trematoda and Cestoda.

Over 3000 species of endoparasitic flukes are known from the world on various hosts from fishes to man. Different species attack different parts of the host ; some inhabit the gut, others the bile ducts, lungs, urinary bladder or blood vessels.

Classification

Class TREMATODA

Subclass 1. *MONOGENEA*. Ectoparasites without metamorphosis ; no intermediate hosts. Example : *Polystoma*.

Subclass 2. *DIGENEA*. Endoparasites with metamorphosis and intermediate hosts.

Order i. GASTEROSTOMATA. Mouth near the middle of body. Example : *Bucephalus*.

Order ii. PROSTOMATA. Mouth at the anterior end and surrounded by sucker. Examples: *Fasciola*, *Schistosoma*.

1 LIVERFLUKE

Bionomics.—The liverflukes are parasitic in the liver and bile ducts of sheep, goat, ox, horse, ass, pig, cat, rabbit, man and various other animals. They cause the disease called "liver rot", which often ends fatally. The larval stages are passed in snails or in snails and fishes. Several species of liverflukes are known : 1. *Fasciola hepatica* the cosmopolitan sheep liverfluke,

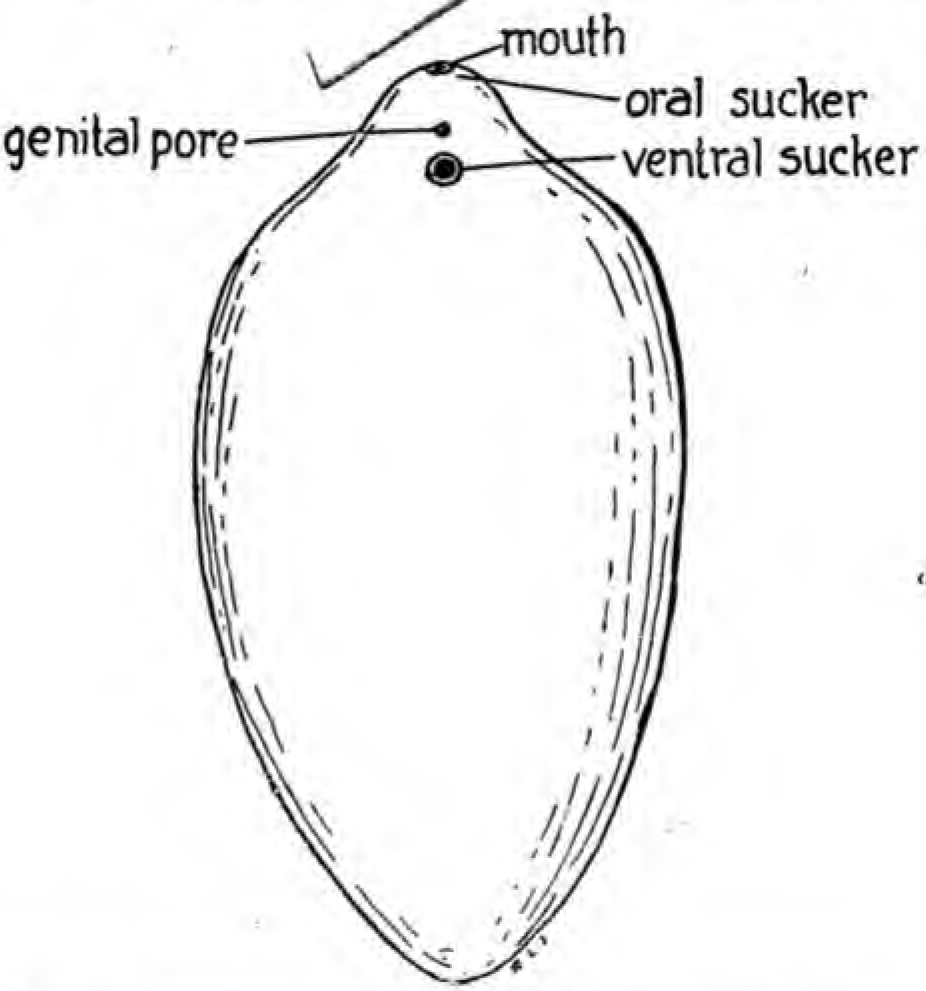


FIG. 159. *Fasciola hepatica*. External features in ventral view.

2. *Fasciola gigantea* the giant liverfluke from America, Europe, Asia and Africa, 3. *Fascioloides magna* from Europe and America, 4. *Dicrocoelium dendriticum* (formerly *Fasciola lanceolatum*), 5. *Opisthorchis sinensis* the Chinese liverfluke, and 6. *Eurytrema pancreaticum* of sheep and goat from India and America. *Fasciola hepatica* (formerly called *Distomum hepaticum*) is the commonest species which is widely distributed all over the world. Its systematic position is given below:

C. M. Malentew

8th February 1955

Phylum PLATYHELMINTHES
Class *TREMATODA*
Subclass DIGENEA
Family Fasciolidae
Genus *Fasciola*
Species *hepatica*.

8th March 1953
→ 8th Feb. 19

Structure.—The sexually mature liverfluke occurs in the bile ducts of its hosts. Its body is flat like a leaf, about 30 mm long, broadly rounded anteriorly and bluntly pointed behind. There is a blunt triangular projection at the anterior end of the body. The tip of this projection bears a cup-shaped muscular ***anterior sucker*** surrounding the mouth.

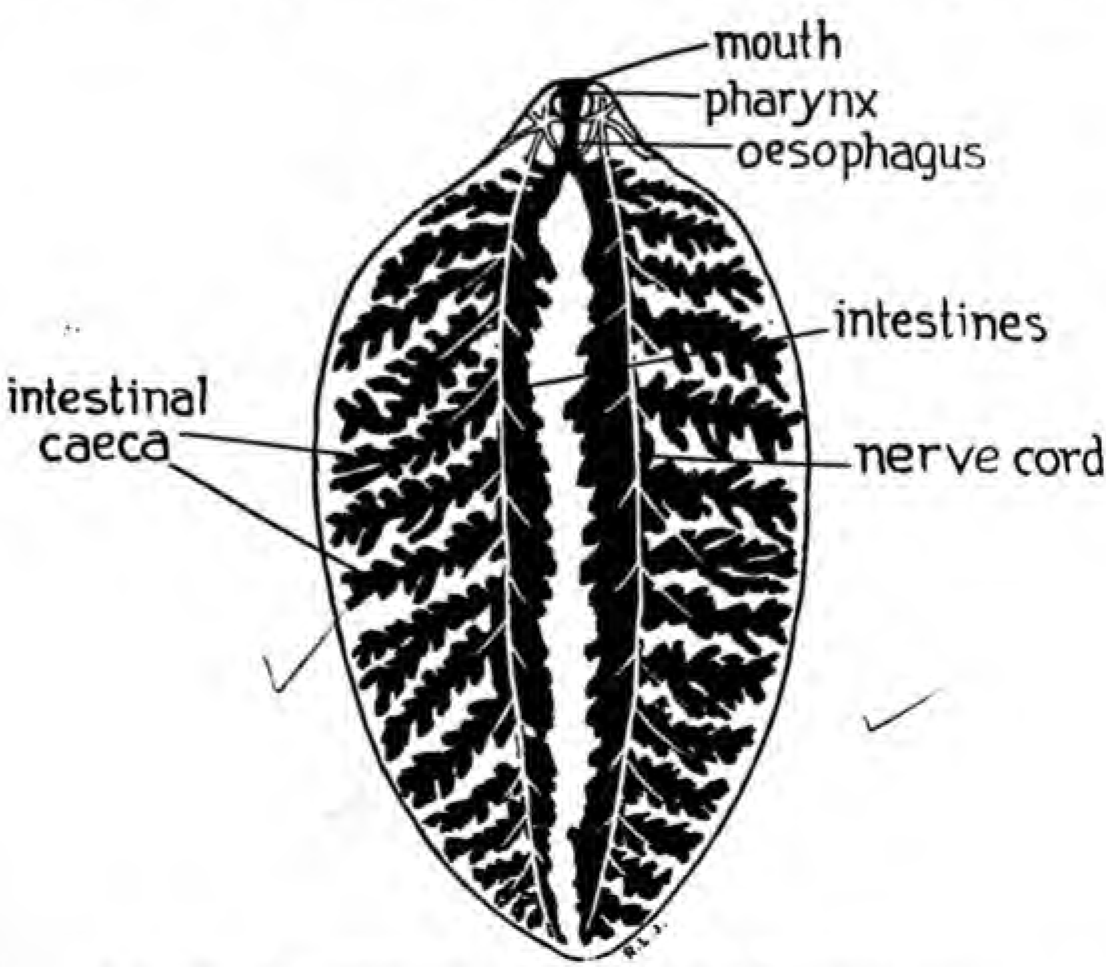


FIG. 160. Alimentary and nervous systems of *Fasciola hepatica*.

Just behind the base of this projection, the ***ventral*** or ***posterior sucker*** lies on the median ventral line. The ventral sucker serves for securing an anchorage in the host. Between these two suckers is the ***genital opening***.

On the dorsal surface is the opening of the ***Laurer-Steida canal*** in the median line. At the posterior end of the body the ***excretory pore*** opens to the outside.

The digestive system comprises a muscular pharynx behind the mouth, a short oesophagus, which bifurcates into two enterons in front of the ventral sucker. The enterons run backward, one on either side of the median longitudinal line and give off a number of ***diverticula,*** reaching the margin of the body. The enterons end blindly, there being no anus.

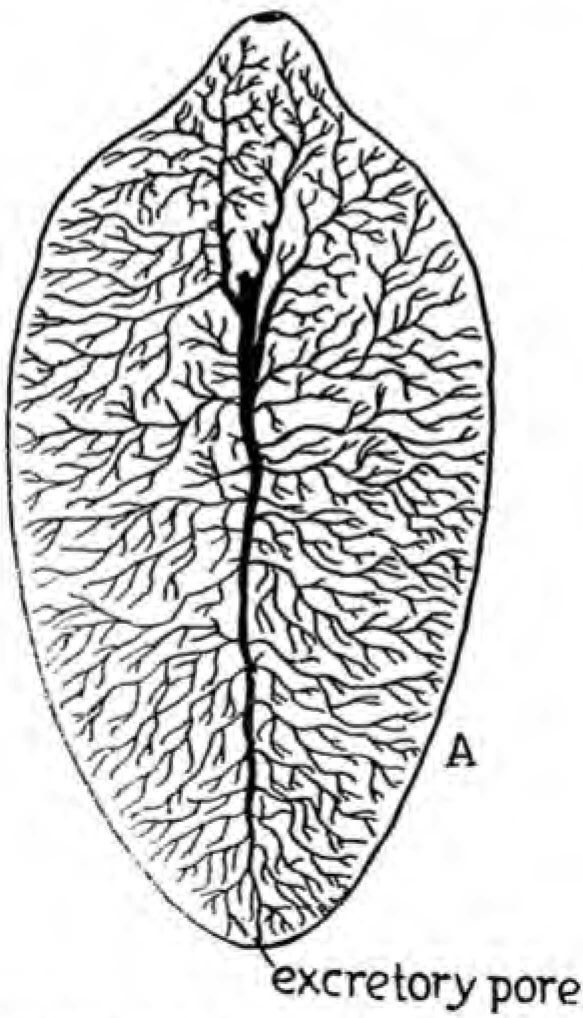


FIG. 161 Excretory system of *Fasciola hepatica* in ventral view.

The excretory system consists of minute transparent ***flame cells*** with vibrating cilia. The flame cells continue as fine convoluted tubules, forming a net-work in every part of the body These tubules open into a main duct, which runs backward to open to the exterior by the excretory pore.

The nervous system comprises a nerve ring round the pharynx with a median ventral ganglion and a pair of lateral ganglia. Paired lateral

nerve cords arise from the lateral ganglia and run back to the posterior end of the body, giving off nerves at intervals.

The liverfluke is a ***hermaphrodite*** : both ovaries and testes develop in the same individual. The testes are paired, highly branched tubes lying along the median longitudinal line of the body. The branches open into a ***vas deferens***. The vasa deferentia of the two sides unite together into a ***seminal vesicle*** near the ventral sucker. From the seminal vesicle, a ***ductus ejaculatorius*** leads the semen to a cylindrical muscular ***penis*** The penis ends in the genital aperture.

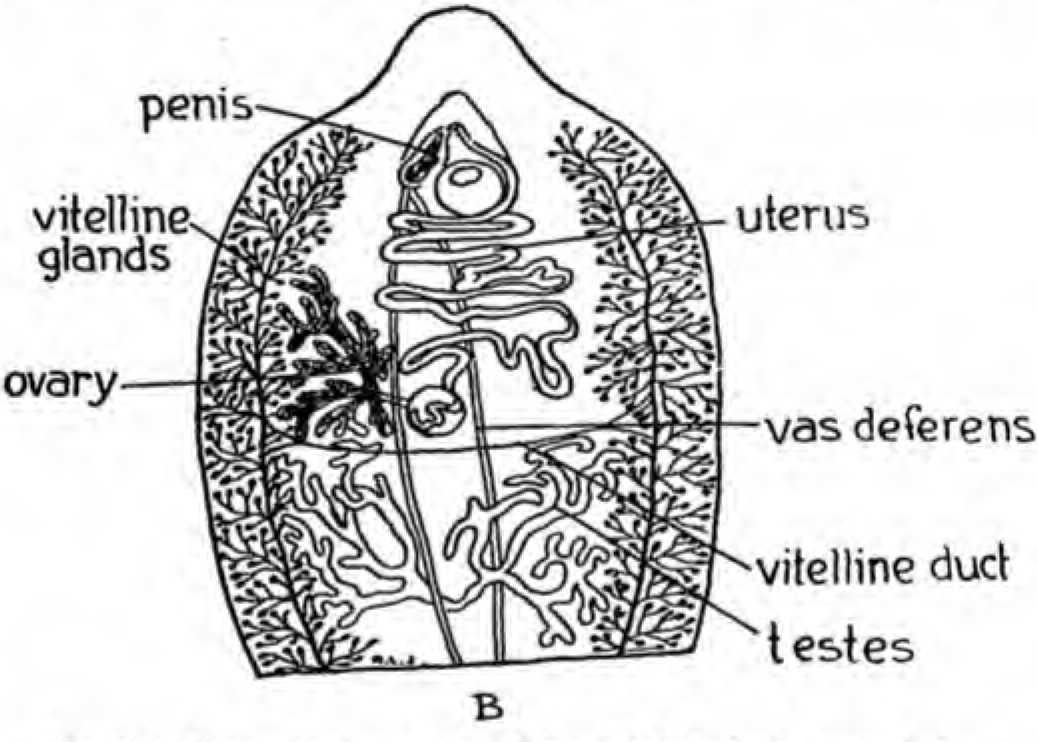


FIG. 162. Reproductive system of *Fasciola hepatica* in ventral view.

The ovary is an unpaired branched tube on the right side of the body. The tubes open into an ***oviduct***. Vitelline glands secrete an albuminous fluid through a vitelline duct, which opens into the oviduct. At this point a ***shell gland*** surrounds the oviduct, which now continues as a much convoluted ***uterus*** to the genital aperture.

Nutrition, respiration and excretion.—Formerly it was supposed that the liverfluke lives chiefly upon the blood of the host, but it has now been shown that the gut of the liverfluke contains neither haemoglobin nor corpuscles. When hungry, the flukes migrate into the smaller bile ducts and feed upon the liver tissues and absorb the glycogen stored therein.

Respiration in the liverfluke is ***anaerobic***: oxygen is not necessary for respiration. Respiration is essentially decomposing matter for the sake of energy. The liverfluke gains energy by fermenting glycogen in the absence of air. Carbon dioxide and fatty acids are produced as wastes. The metabolic wastes are separated by the flame cells and expelled through ciliary action by way of the excretory pore.

Life-history — The life-history of the liverfluke is perhaps one of the most complicated among animals. The liverfluke is a hermaphrodite. When two flukes copulate, the sperm is probably transferred to the Laurer-Steida canal. From here the sperms are later shed on the ova as they pass down the uterus. A single liverfluke produces over 500,000 eggs during her life. Each egg is covered by a chitinous shell, with a lid or ***operculum*** on one side and is provided with yolk for the developing embryo. A single sheep is often infested with nearly two hundred liverflukes. The sheep therefore scatters about the unbelievably prodigeous number of a hundred million eggs of the liverfluke! These eggs are already in an advanced state of development. The liverflukes discharge the ova into the bile ducts, whence they pass down into the intestine of the sheep and are voided with faeces. The eggs are beset with innumerable chances of failure. If they are dropped in dry places they are destined to die. At temperatures below 10°C they do not develop but remain alive for several months, waiting for favourable conditions. If however the sheep has dropped the faeces containing the ova in warm damp places, especially on the immediate bank of a pond or stream, the embryo completes its development in about ten days.

From each egg emerges a minute larva by pushing off the operculum of the egg. This is the ***miracidium*** larva. It is pyriform and clothed with cilia all over. The cilia are the locomotor organs of the miracidium. The larva has a pointed ***rostrum*** or beak anteriorly. There are two ***eye spots*** composed of crescentic pigmented cells. There is no gut or endoderm but there are circular and longitudinal muscles and paired excretory organs called ***nephridia***. Each nephridium is composed of a flame cell. The posterior half of the body is filled with ***germ cells*** that are capable of giving rise to a new generation of larva of another type. There is also a nerve ganglion.

If the miracidium hatches in water, it swims actively for about eight hours. At the end of this period it is destined to die, unless it chances to meet with certain species of snails (*Limnea* spp.). While swimming, the miracidium tests all objects with which it comes into contact. Millions of

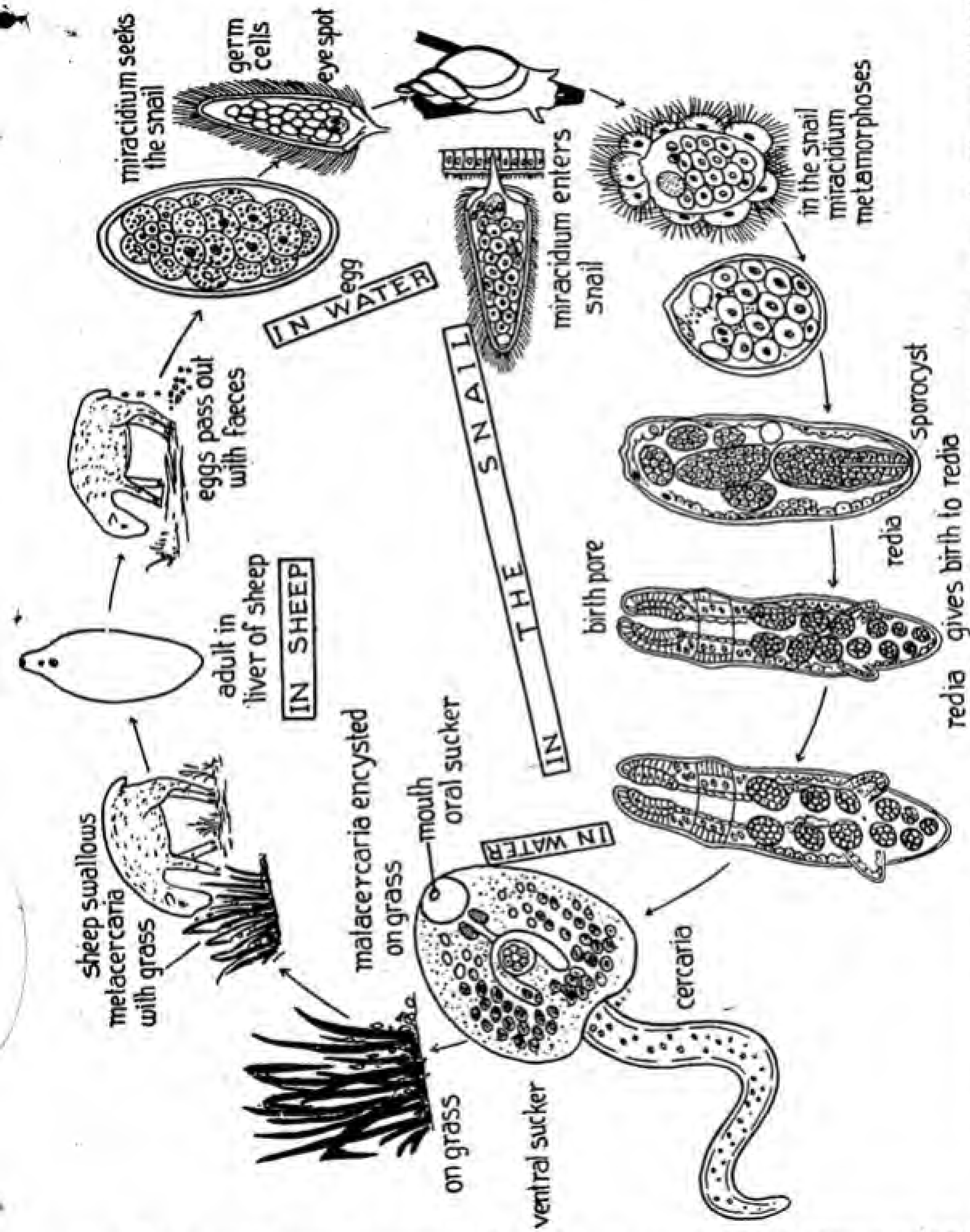


FIG. 163. Life-cycle of *Fasciola hepatica*. (*Original diagram with details of figures of the stages after Thomas and after Leuckart's Parasiten des Menschen*).

miracidia never have the chance of coming across the right species of snail. If however one meets a snail, it immediately bores its way into the soft body of the snail by using the rostrum as a gimlet, spinning round and round till

it has entirely vanished inside. Even after entering the right species of the snail, the chances of survival are not by any means bright for the miracidium. It must also have happened to bore into the right place in the snail! The miracidia which bore into the muscular foot of the snail perish but those that enter the softer parts like the pulmonary chamber survive. Thence the miracidia migrate by way of the blood vessels or lymphatics to the liver of the snail. Here they undergo metamorphosis. The cilia are lost and the body swells up into a spherical sac-like ***sporocyst***. Each germinal cell now divides repeatedly without fertilization and gives rise to ***germinal balls*** or blastula. The blastula undergoes gastrulation and becomes a second kind of larva called ***redia***. In each sporocyst about eight redia are produced.

A redia is an elongate cylindrical larva with mouth, pharynx and unbranched enteron, having no eye spots. Flame cells, circular and longitudinal muscles are present. The body is packed with germ cells. Finally the redia breaks through the wall of the sporocyst and goes into the tissues of the snail, particularly the liver. When full grown, the redia reproduces in its turn, again without fertilization; two or three generations of rediae are thus born. Ultimately the germ cells give birth to another type of larva called ***cercaria***. By this time the snail is usually killed.

The cercariae escape from the redia by the ***birth pore***. A cercaria looks like a tadpole with an enormous head and a long tail. It has oral and ventral suckers, mouth, pharynx, oesophagus bifurcating into a pair of tubular enterons and excretory canals. Immediately after birth, the cercaria burrows its way out of the snail into the water and leads a free-swimming life for a short while. Finally it wriggles out of water on to some blade of grass or leaf of other aquatic plants. The cercaria now loses the tail and becomes a ***metacercaria***. A cyst wall is secreted. The encysted metacercariae are viable for some months. If this blade of grass is eaten by some sheep or other herbivorous animal, the cysts dissolve in its stomach and thus the metacercariae are liberated. The metacercariae have most of the organs of the adult liverfluke except the gonads. From the stomach they pass into the intestine and thence up into the liver, where they slowly grow into the adult liverflukes.

The complex life-history of the liverfluke may be summarized as follows:

A. IN SHEEP

The adult lives in the bile ducts of sheep and various other mammals. Its eggs pass down into the intestine of the host and are voided with the faeces.

B. IN WATER

A free-swimming ciliated miracidium hatches from the eggs, which happen to be dropped in or near water. The miracidia swim for some hours in search of snails.

C. IN SNAIL

1. The miracidium burrows into the soft tissues of particular species of fresh-water snails and reaches the pulmonary chamber. Here the miracidium becomes a sac-like sporocyst.
2. The sporocysts develop into redia.
3. Rediae reproduce asexually for three or four generations and give rise to more rediae.
4. Rediae produce cercariae.

D. IN WATER

Cercariae are free-swimming for some time.

E. ON GRASS

The cercariae climb on to blades of grass and become encysted as metacercariae.

F. IN SHEEP

If these blades of grass are eaten by sheep, the cysts dissolve in its stomach, the metacercariae escape as young liverflukes. They ascend up the bile ducts, reach the liver and become adults in course of time.

SIGNIFICANCE OF THE SIMPLE STRUCTURE AND THE COMPLICATED LIFE-HISTORY

Parasitic Adaptations.—The simple structure and the complicated life-history of the liverfluke are adaptations for an endoparasitic mode of life. The simple organization of the liverfluke is not a primitive condition but is the result of degeneration that comes from a sheltered life led by an endoparasite. The complicated life-cycle is a device to minimize the effect of numerous failures that beset the path of the liverfluke. The various adaptations of an endoparasite are directed to two ends: 1. self preservation and 2. race preservation. The simple organization ensures the first and the complicated life-cycle guarantees the second.

The liverfluke leads a protected life, safe within the host and has not to work for a living. It has plenty of ready-made and predigested food, viz. glycogen stored in the liver. It is thus saved from spending material and energy in building organs of locomotion, skeleton and special senses. It has no faeces to void and thus has no anus. As there is no need for digestion, there is also no need for special circulatory system. The alimentary canal itself forms the circulatory system: the branched gut carries the food to every

part of the body. Respiration is carried out in absence of oxygen. Even an endoparasite has to expel metabolic wastes from various parts of the body and thus the excretory system of the liverfluke is itself branched to facilitate their collection. Thus the branched condition of the viscera is the result of parasitic mode of life. The liverfluke has eliminated the expenditure of a large amount of material and vital energy by not building many organs that are unnecessary. The material thus saved is used up in increasing the reproductive capacity.

The number of eggs produced by an animal constitutes its ***reproductive potential***. The liverfluke has a very high reproductive potential : each individual produces nearly half a million ova. These ova however cannot develop in the sheep, in which the parent lived, because the sheep is destined to die from the effects of the attack. The progeny must therefore reach another sheep. Many chances of failure beset the developing embryo, such as unfavourable conditions of temperature, humidity, locality, etc. Thousands perish. Even if we imagine that all the ova hatch into miracidia, there is no guarantee that every one of the larvae will succeed in entering the right species of snail. Unless therefore an enormous number of ova are scattered, there is no hope even for one egg reaching maturity. The high reproductive potential is further boosted up by ***paedogenesis***, *i.e.* reproduction by the larvae. A single miracidium may give rise to about 10,000 cercariae. Thus it is ensured that at least one or two of the metacercariae are swallowed by a sheep.

A high reproductive potential, paedogenesis, combination of sexual and asexual modes of reproduction, actively swimming larvae and different types of larvae are various adaptations for a parasitic life. These adaptations ensure the survival of the race.

Effect of parasitism by liverfluke on the hosts.—The liverfluke is as truly parasitic in the snail as in sheep. The presence of the parasites affects both the hosts in a number of ways.

The effect on the sheep.—The parasite feeds on the glycogen stored up in the liver of the sheep. This drains away a considerable amount of vitality of the sheep. Enormous numbers of the fluke often block up the bile ducts and interfere with the proper functioning of the liver tissues. The metabolic wastes of the liverfluke are shed into the bile ducts and when absorbed into the body act as toxins to the sheep. Damage is also done by the migration of metacercariae, which literally eat their way through various organs, before finally reaching the liver. This causes

ulcers with disastrous consequences. The combined effect of all these is slow weakening and death of the host.

Effect on the snail.—The effects of the attack by the liverfluke larvae on the snail are both mechanical and chemical. The rediae eat their way through to the liver from the pulmonary chamber. The toxins secreted by the parasite seriously disturb the metabolism of the snail. The organs invaded by the parasite cease to function properly. They waste their energies in getting rid of the toxins and thus become atrophied in course of time. Sometimes gigantism of the snail arises from the attack of flukes.

Immunity of hosts to attack of liverflukes.—Both larvae and adults of the liverflukes show marked preference to certain hosts and fail to develop in others. The cercaria of *Fasciola hepatica* shows a preference to the fresh-water snail *Limnaea truncatula*, though it may sometimes attack other species. Hosts often produce antibodies which confer immunity from the attack of the liverflukes. For example, *Fasciolopsis buski* cannot develop in rabbits, monkeys, cat, sheep, rat or oxen but readily do so in man and pig.

Natural enemies.—Liverflukes have their own natural enemies to answer. They have their own parasites: ***hyperparasites***, that is, parasites on a parasite! Several Protozoa, for example, *Nosema*, are parasitic on the flukes. The eggs of *Fusciolopsis buski* are attacked by Chytridiaceae. The cercariae of some trematodes, for example *Cotylurus*, parasitize the rediae of liverfluke.

Some Other Important Trematodes

Bloodflukes.—The bloodflukes are important parasites of man in Egypt, South Africa, Madagascar, China and Japan.

The sexes are separate. The male is large and has the sides of its body folded over to form a permanent ***gynaecophorous groove***, in which the slender but elongate female is permanently carried in copulation (Fig. 164). Such paired adults occur in hundreds in the veins from intestine, kidneys and urinary bladder. They cling to the wall of the blood vessel by their suckers and feed on the blood. They ascend up the veins against the blood stream in order to lay eggs in the capillaries. The capillaries become so gorged up with the eggs that they rupture and bleeding takes place in the intestine or urinary bladder. The eggs pass out with faeces or with urine. The miracidia hatch out on contact of the eggs with water and attack the snails of the genera *Bulinus* or *Planorbis* and become sporocysts. The sporocysts produce cercariae, which escape

into the water. New infection of man occurs by the cercaria burrowing into him while bathing or through his drinking water. The young worm makes its way into a blood vessel and is then carried to the portal vein, where the females and the males copulate. The attack by bloodflukes causes a disease called ***schistosomiasis,*** characterized by pain, cough, rash, dysentery, haematury and anaemia.

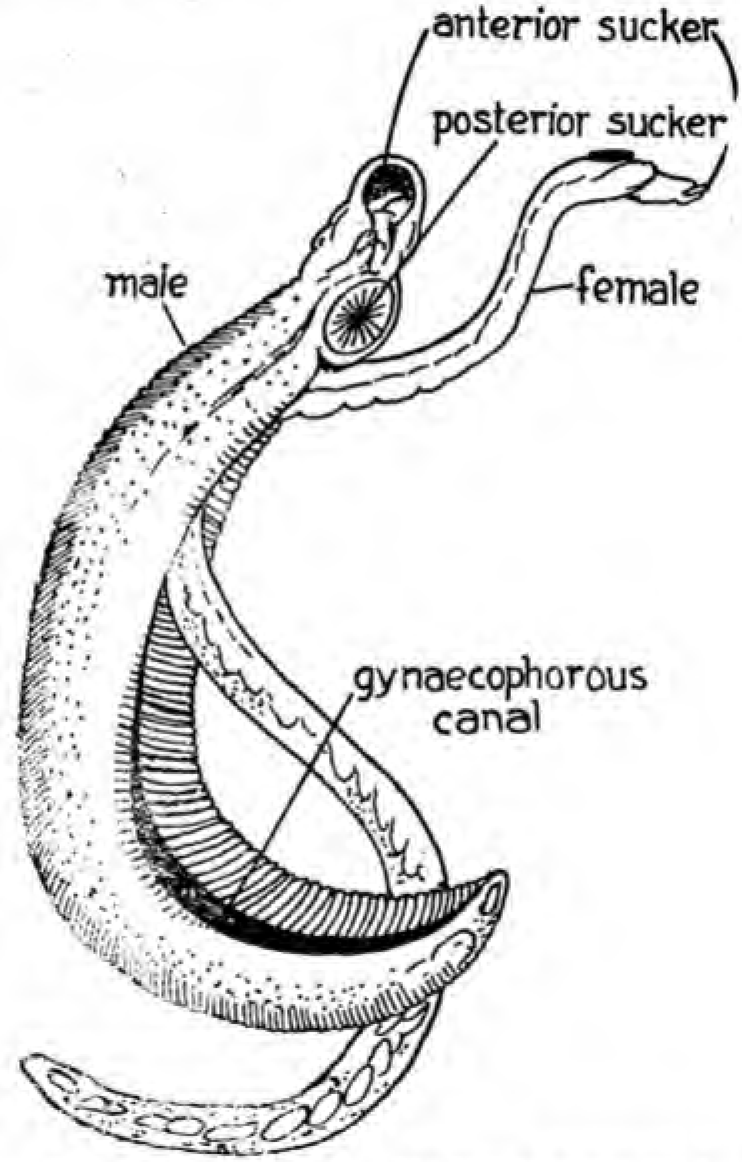


FIG. 164. *Schistosomia haematobia* The female is carried by the male in the gynaecophorous canal. (*From R. Hertwig Lehrbuch der Zoologie, Gustav Fischer*).

There are several species of bloodflukes :

1. *Schistosomia* (formerly *Bilharzia*) *haematobia* (Fig. 164) is the the most wide-spread and dangerous of all the bloodflukes. It is abundant in the Mediterranean countries and also occurs in various parts of

Asia as well as Australia and America. In addition to man, it attacks rats and mice also. 2. *Schistosomia japonicum* is peculiar to China and Japan, where it attacks man, cat, dog, horse and cattle. 3. *Schistosomia indicum* occurs in sheep and horse in India. 4. *Schistosomia bovis* infests sheep and cattle in India, Malaya, Indo-China and Africa.

Lungfluke.—The lungfluke, *Paragonimus westermanii*, occurs in the lungs of man in China, Japan, the Philippines and South America. It also attacks various other mammals like cat, dog and pig. The eggs are voided with the sputum and the miracidia bore into the snails of the genus *Melania* and become sporocysts. One or two generations of rediae are produced asexually in the snail and finally cercariae with short tails find a second intermediate host in fresh-water Crustacea, like crabs and crayfish. In the second intermediate host they become encysted as metacercariae. By eating raw crabs or crayfish, as is usually done in China, man becomes infested with the lungfluke.

Intestinal fluke—The intestinal fluke, *Fasciolopsis buski*, lives in the intestine of man and pig in India, China, Indo-China and East Indies. Miracidia attack snails and cercariae are encysted on water-nuts (*Trapa natans*; Hind. singhara or paniphal). Eating raw water-nuts introduces the parasite into man.

CESTOIDEA

The CESTOIDEA are slender, elongate, flat and ribbon-shaped worms, popularly called "tapeworms", that are exclusively parasitic in various animals. Their body is often composed of short ***proglottids*** and a knob-like ***scolex***. Some of them are minute while others exceed twenty-five feet in length. They have suckers and hooks for attachment. They lack cilia, mouth or alimentary canal. The food is absorbed directly through the body wall. The excretory system is well developed and the nervous system comprises a nerve-ring and three pairs of nerve cords. The reproductive organs are the best developed of the systems.

The life-history of the tapeworms is complicated and includes changes of one or more intermediate hosts and larval types. Tapeworms attack various mammals, birds, reptiles, amphibia, fishes and arthropods. Nearly two thousand species of tapeworms are so far known.

Classification.

Phylum PLATYHELMINTHES

Class *CESTOIDEA*. No alimentary canal, body composed of numerous sections, each of which is sexually complete.

Subclass 1. CESTODARIA. Only one section in body and single set of sexual organs; parasitic in primitive fishes.

Subclass 2. CESTODA. Many sections and sets of reproductive organs; bulk of the tapeworms.

Order i. Pseudophyllidea. Scolex with a pair of suckers but no hooks; two or three larval stages in Crustacea and fishes. Example: *Dibothriocephalus latus* (fish tapeworm).

Order ii. Tetrarhynchidea. Scolex with two to four suckers and four proboscids bearing numerous spines Larvae in marine Invertebrates and adults in fishes. Example: *Tetrarhynchus.*

Order iii. Tetraphyllidea. Scolex with four suckers; in fishes and reptiles Example: *Phyllobothrium.*

Order iv. Diphyllidea. Scolex with two suckers and many hooks and about one-fourth length of body; larvae in Crustacea and Mollusca and adults in fish. Example: *Echinobothrium.*

Order v. Cyclophyllidea. Scolex with four cup-shaped suckers and a rostellum armed with hooks. Examples: *Taenia, Echinococcus* and *Hymenolepis.*

2. TAPEWORM

Occurrence and systematic position.—Tapeworms occur in all parts of the world. About half a dozen species infest man: *Taenia solium* the pork tapeworm, 2. *T. saginata* beef tapeworm, 3. *T. pisiformis* cat and dog tapeworm, 4. *Diphyllidium caninum*, dog tapeworm, etc. *Taenia solium.* is the commonest of the tapeworms that attack man. It has been known from ancient times. Infection by this tapeworm is wide-spread in China, Europe and America and is due to eating insufficiently cooked pork. The adults occur in the intestine of man and the larvae in pigs.

Its systematic position is given below:

Phylum PLATYHELMINTHES
Class *CESTOIDEA*
Subclass CESTODA
Order *Cyclophyllidea*
Family Taeniidae
Genus *Taenia*
Species *solium*

Structure.—The pork tapeworm attains a length of about 30 feet when mature. It has a minute knob-like head or ***scolex*** by means of which the tapeworm fixes itself to the wall of the intestine. The scolex has four muscular cup-shaped suckers or ***acetabula.*** The tip of the scolex is elevated into an evertible ***rostellum,*** bearing a double crown of about twenty-eight ***hooks.*** Some of the hooks are large and others are small. The suckers and hooks serve to fasten the scolex to the wall of the intestine of the host. Behind the scolex there is a narrow elongate unsegmented ***neck.*** The neck is followed by the ***strobila*** or the rest of the body. The strobila is composed of a series of nearly one thousand

partitions called ***proglottids.*** While the scolex is imbedded in the mucus of the intestinal wall, the strobila hangs freely in the cavity of the intestine. The proglottids become larger and larger posteriorly. New proglottids are constantly budded off from the neck. The oldest proglottid is thus the posterior-most. When mature, it gets detatched and is passed out with the faeces of the host.

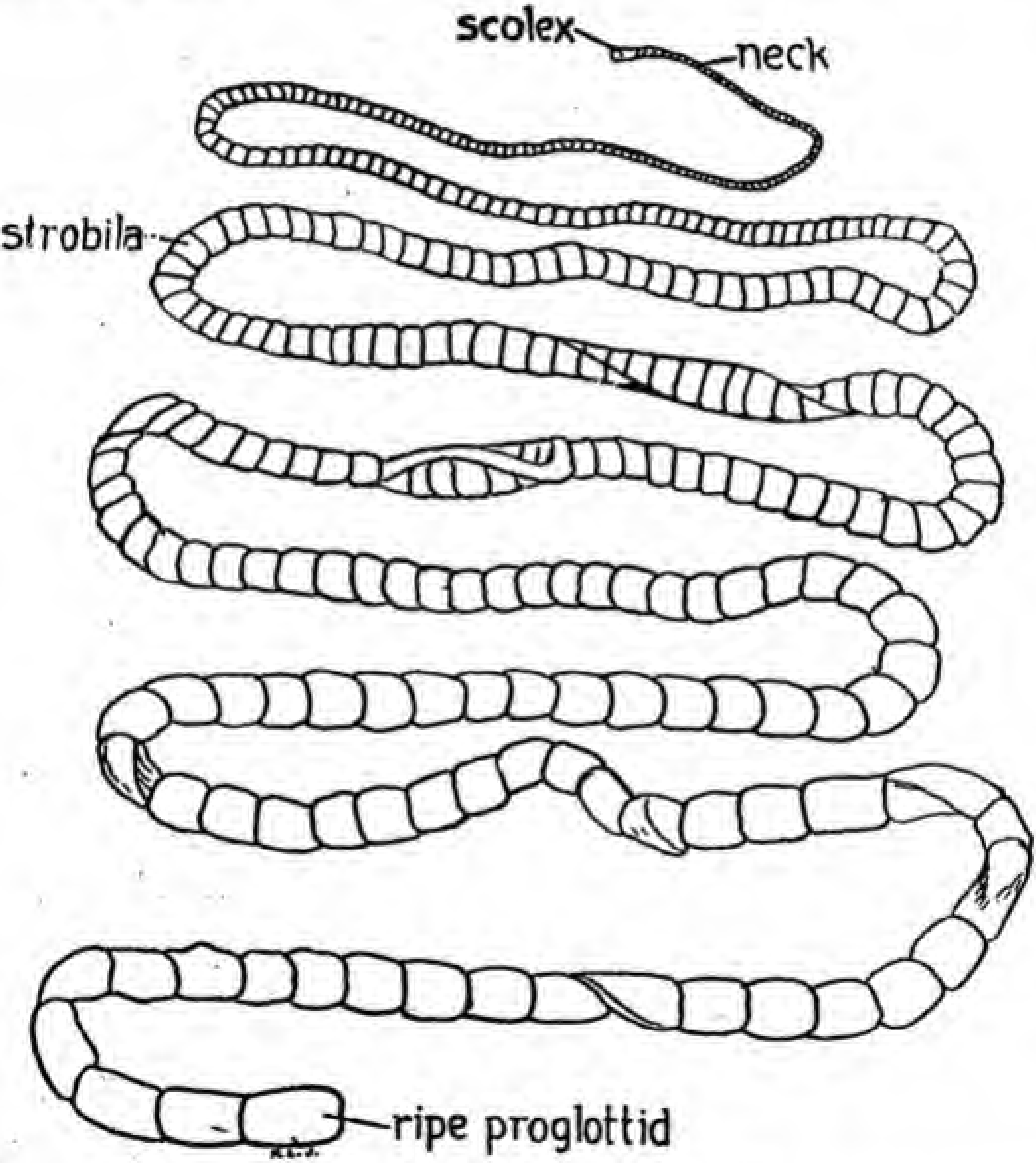


FIG. 165. Pork tapeworm *Taenia solium.*

The body is covered by resistant, elastic, thin cuticle. The bulk of the body cavity is filled up by parenchyma. There is a well developed muscular system composed of circular and longitudinal bundles. There is no mouth, anus or alimentary canal. The tapeworms live in the intestine, where

they are actually soaked up in digested food ready to be absorbed directly by the general surface of the body. Tapeworms do not even have to feed.

The excretory system comprises the flame cells connected to much branched tubules. These tubules unite to form four longitudinal vessels; two running along each lateral margin, one dorsal and one ventral. They extend from the scolex to the last proglottid, where they open posteriorly by the excretory pores. The longitudinal vessels are connected by a ring-like vessel in the scolex and by a transverse branch posteriorly in each proglottid.

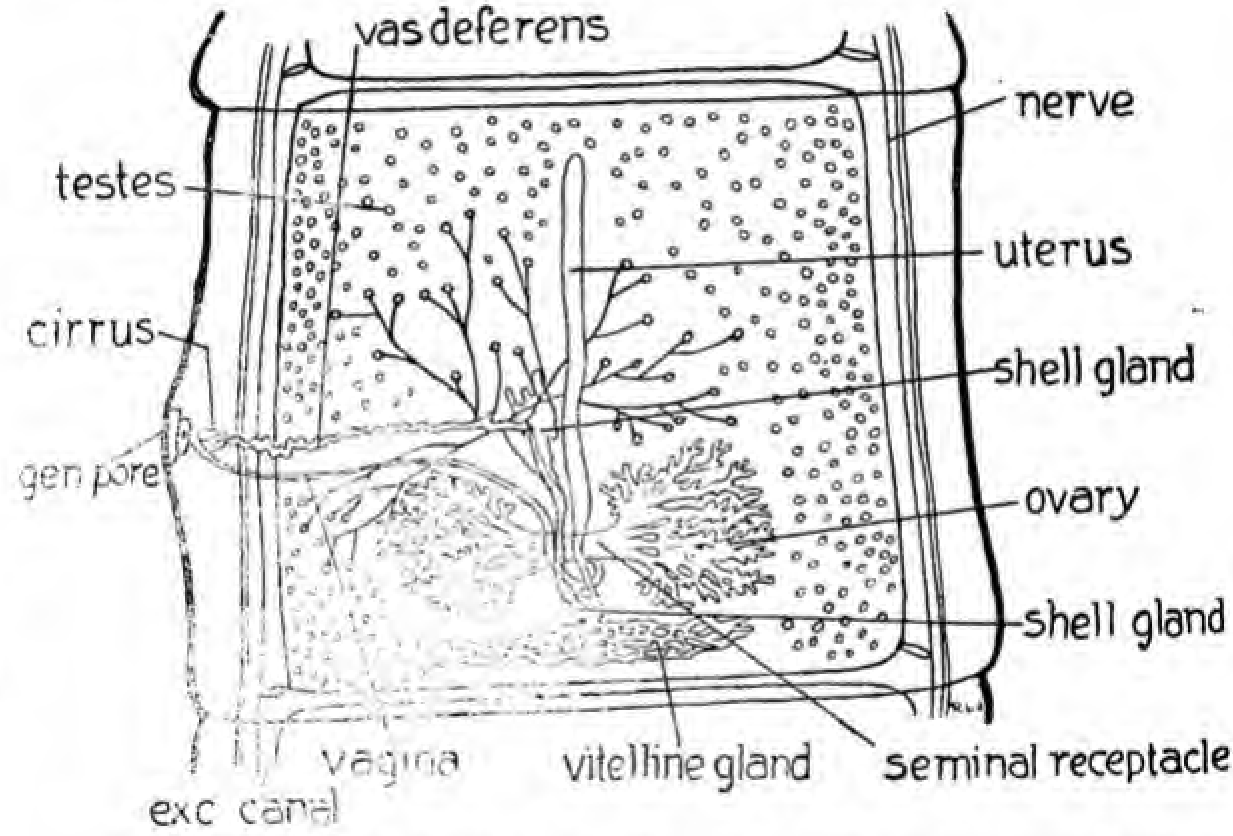


FIG. 166. A ripe proglottid of *Taenia solium* showing the reproductive organs. (*After Leuckart's Parasiten des Menschen*).

The nervous system comprises a nerve-ring in the scolex. Nerves are given off from the ring to the suckers and to the rostellum. The ring is joined to three pairs of longitudinal nerve cords extending backward into every proglottid.

The tapeworm is a hermaphrodite. Except the first two hundred, every proglottid has a complete set of reproductive organs, comparable to those of the liverfluke. The male reproductive organs mature first. The male genital aperture and the vagina open to the outside very close

together on the lateral margins irregularly alternately in each proglottid. The testes are very numerous : a proglottid has often five hundred testes. A ***vas efferens*** arises from each testes. The vasa efferentia unite into a coiled ***vas deferens***. The terminal part of the vas deferens is the ***cirrus*** or penis. It is surrounded by a ***cirrus sac***, which serves to erect the penis during copulation.

The ovary is a bilobed mass in the posterior part of the proglottids. Each ovary is a branched tube opening into the median oviduct. The ***vitelline*** gland and the ***shell*** gland are located behind the ovary. The uterus does not open to the exterior of the proglottid. The eggs contained in the uterus are set free by the bursting of the proglottid and of the uterus In the gravid proglottid the testes and ovaries become atrophied.

Spermatozoa are transferred by the evertible cirrus to the oviduct. Sperms from the same proglottid or from a different proglottid or from the proglottids of another individual may fertilize the ova.

Life-history —Two hosts are necessary for the tapeworm to complete its life-history. The zygotes, with which the ripe proglottids are gorged, undergo the early embryonic development in the human intestine. Ultimately they develop into a spherical ***hexacanth*** or six-hooked embryo, often also called ***onchosphere.*** The hexacanth is enclosed within the egg shell. They are incapable of developing into tapeworms in the human host. The egg shells are liberated by the bursting of the proglottids or the entire gravid proglottid are expelled with faeces. The hexacanths cannot escape from the egg shell. If a pig devours the infected faeces, the proglottids and thousands of hexacanths are swallowed. In the stomach of the pigs, the proglottids and egg shells are digested and the hexacanths are thus set free. They pass down with the food into the intestine. With the help of the six hooks the hexacanths start burrowing through the intestinal walls into the intestinal blood vessels and are carried by the venous blood stream to various parts of the body. Finally on reaching the voluntary muscles, they settle down and in three or four weeks become oval bladder-like sacs about a quarter of an inch long and filled with a clear fluid. These are the ***cysticercus*** or the bladderworm larvae.

The cysticercus secretes a cyst around and the muscles of the host also secrete an isolating cyst around the cysticercus. In due course the wall of the cysticercus becomes thickened at a certain spot, which then invaginates into a hollow finger-like ***proscolex*** or the rudiment of the future scolex. This invagination of the wall of the bladderworm grows deeper, so that the proscolex becomes longer and is also sharply bent at right angles to one side as a tube.

From the base of this tube four suckers and the corona of hooks develop. The proscolex is later evaginated or turned inside out bringing the suckers and hooks to the surface. This final change to the scolex cannot

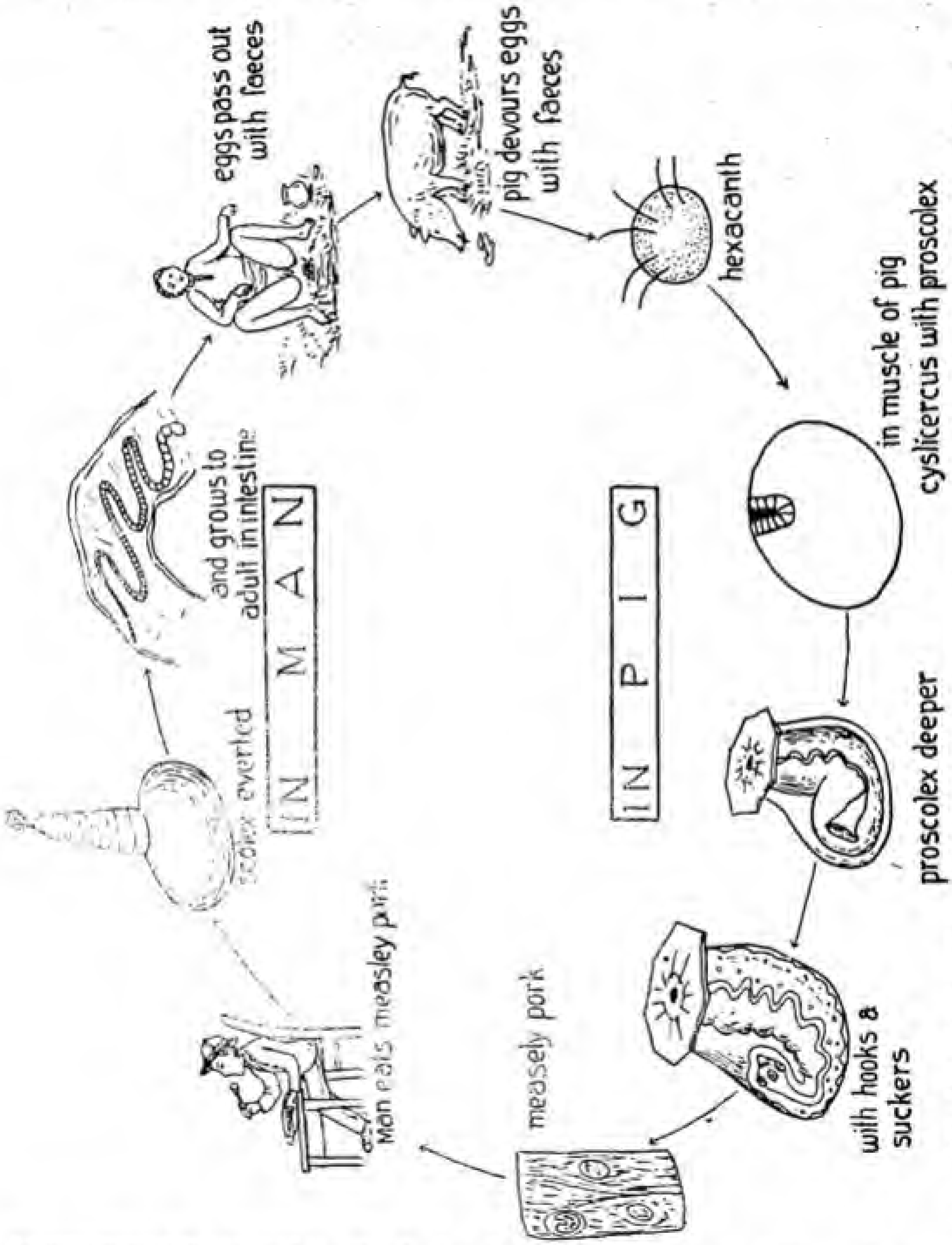


FIG. 167. Life cycle of the pork tapeworm (*Taenia solium*. (*Original diagram with figures of the stages after Leckart's Parasiten des Menschen.*)

however take place unless the flesh of the pig is eaten by man. When man eats improperly cooked or raw "measly pork" (as pork infested with cysticercus is called), the cyst walls are digested in the stomach and the

bladderworms gain their freedom. The proscolex is everted as scolex and the bladder is lost. The scolex now fixes itself to the mucous lining of the intestine. The scolex and its neck absorb the rich nutrient liquid comprising the digested food in the intestine and steadily grow. The neck buds off proglottids and in about ten to twelve weeks the first ripe proglottids are ready to be detached.

SYNOPSIS OF THE LIFE-HISTORY

I. IN MAN.

1. Eggs are fertilized.
2. The embryonic development is completed and onchespheres or hexacanth embryos are enclosed in the egg shell.
3. The gravid proglottids break off and pass out with faeces.

II. IN PIG

1. The pig swallows human faeces with the embryos.
2. The proglottids and the egg shells are digested in the stomach.
3. The hexacanths burrow into the intestinal wall and are carried by the blood stream to various organs.
4. Many of them reach the voluntary muscles.
5. They become encysted as cysticercus.
6. The proscolex is invaginated from the wall of the cysticercus.
7. Suckers and hooks develop in the base of the cup-shaped proscolex.

III. IN MAN

1. Man eats pork containing the encysted cysticercus.
2. The cyst walls are dissolved in the stomach and the cysticercus escapes into the intestine.
3. The proscolex is evaginated as scolex and neck.
4. Scolex anchors itself to the intestinal wall.
5. The young tapeworm absorbs nourishment from the digested food passing down the intestine and grows.
6. The neck buds off proglottids.

OTHER TAPEWORMS

1. *Taenia saginata.* The beef tapeworm. This tapeworm is of cosmopolitan occurrence. Its life-history is similar to that of the pig tapeworm but the hexacanths are scattered on grass and pass into the stomach of a grazing cow or ox The cysticercus occur mostly in the pterygoid muscle. Man becomes infested by eating improperly cooked beef containing the cysticercus. The proscolex of the cysticercus has only four suckers but

has no hooks. The adults have often as many as 200 proglottids and the scolex bears four suckers but lacks the crown of hooks.

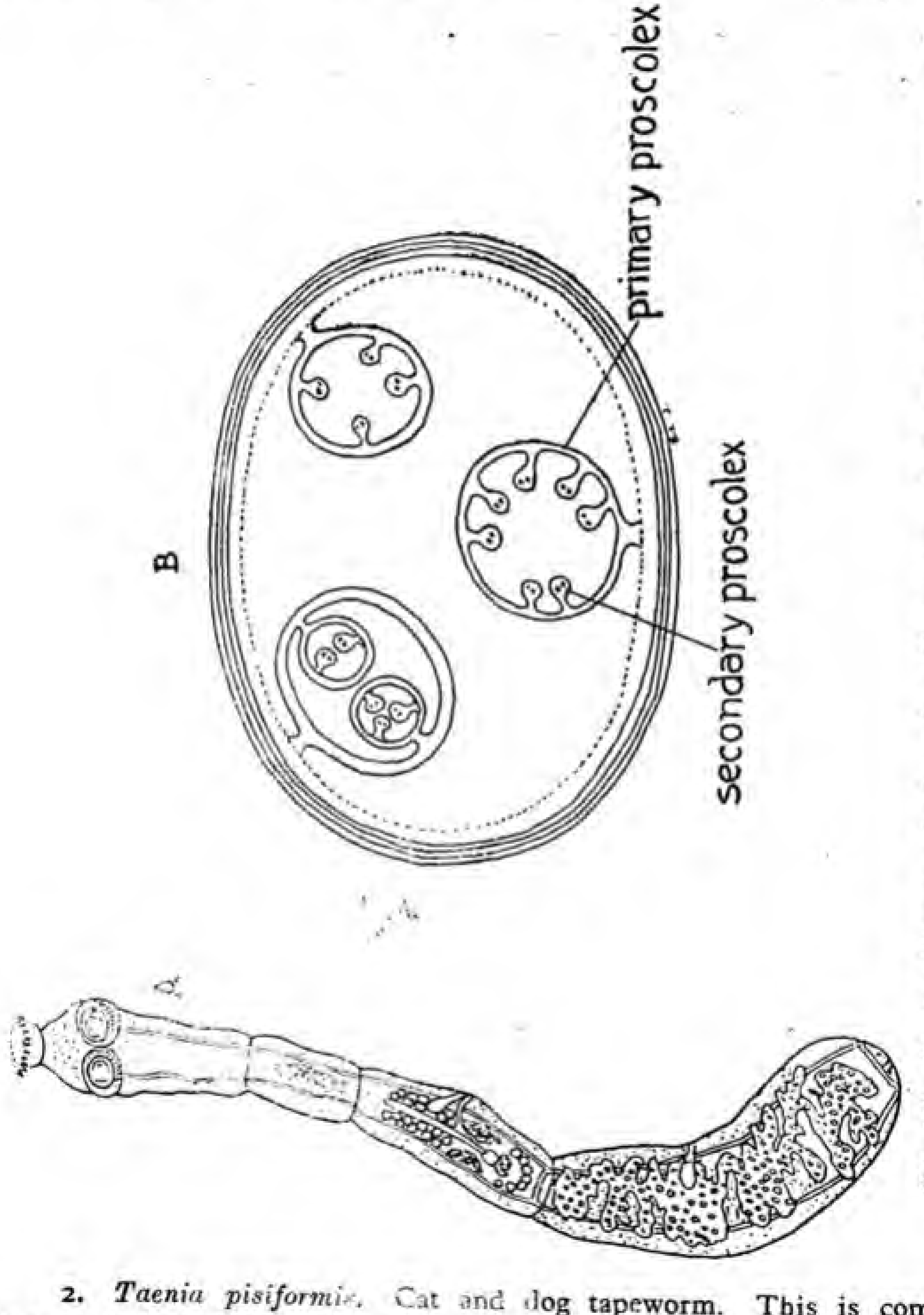


FIG. 168 *Taenia echinococcus* the dog or hydatid tapeworm. B. Diagram of a cyst showing proscoleces and daughter proscoleces. (*After Hatscheck and Leuckart*).

2. *Taenia pisiformis*. Cat and dog tapeworm. This is common all over India. The adults occur in the intestine of cat, dog, tiger, lion and leopard and the cysticercus is encysted in the liver and mesenteries of rabbits and other rodents.

3. *Taenia echinococcus* (formerly *Echinococcus granulosus*). The dog or the hydatid tapeworm is one of the most dangerous tapeworms. The adults infest the intestine of dog. It is a small worm, hardly 5 mm long and is composed of up to five proglottids. The scolex bears about fifty hooks and four suckers. The uterus is a convoluted tube. The last proglottid is gravid. Due to the unclean habits of dogs, the ova occur even in their mouths. Man becomes infected through water or food polluted by dogs or by kissing dogs. The embryo reaches liver, brain and various other vital organs of man. The cysts often attain the size of the head of a child and are full of liquid. The cysticercus gives rise to not one proscolex as in the pig tapeworm but many Each proscolex produces daughter proscoleces, so that out of a single egg a very large number of adult tapeworms are produced. The presence of the cyst gives rise to the hydated disease which often ends fatally. Man is the intermediate host.

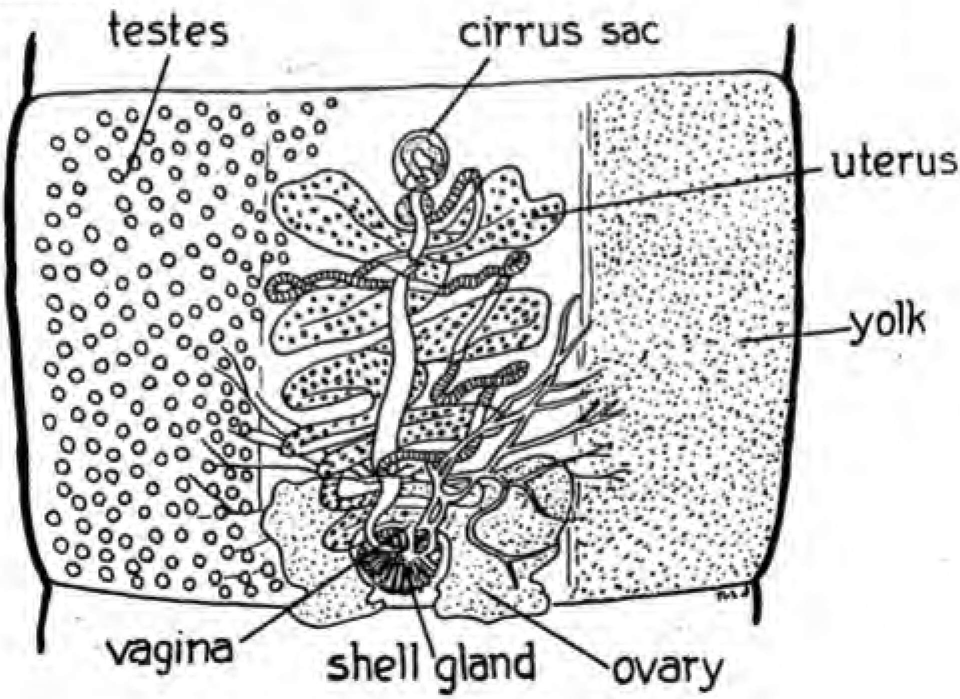


FIG. 169. A ripe proglottid of *Dibothriocephalus latus*.

The adults also occur in jackal and wolves. Other intermediate hosts are apes, monkeys, cattle, sheep, elephant, pig, cat, and various other mammals.

4. *Hymenolepis murina* (formerly *H. nana*). The dwarf tapeworm. Adults occur in human intestine and larvae in intestinal villi. This

tapeworm has no intermediate host. It is common in several parts of Italy and parasitizes rats in India.

5. *Moniezia expansa.* The sheep tapeworm infests the sheep, goat, ox, camel duck, etc as adults. The larvae are found in mites.

6 *Diphyllidium caninum.* The dog tapeworm The adults of this tapeworm live in the intestine of dog and occasionally also cat and man. Larvae in dog louse, dog flea, cat flea and human flea.

7. *Dibothriocephalus latus.* The fish tapeworm. This species is widely distributed in Europe, America, China and Japan. The hosts of this tapeworm include man, dog, cat and several other fish-eating animals. The adults of this tapeworm are the largest after *Taenia saginata* among those that attack man The number of proglottids often reaches upto 4000.

A ciliated embryo hatches from the ova in fresh-water and swims about actively till it finds water-fleas (*Cyclops*), which it penetrates. When these Crustacea are swallowed as food by fish, the second type of larva called ***pleurocercoid*** is formed in the fish. Eating raw fish, as is usually done in China, leads to infection of man by this specis.

SYNOPSIS OF TAPEWORMS OCCURRING IN MAN

I. Man the main host

1.	*Taenia solium*	... Cosmopolitan
2.	,, *saginata*	... ,,
3.	,, *infantis*	... South America
4.	,, *erythraea*	... Abyssinia
5.	,, *philippina*	... Philippines
6.	,, *confusa*	... U. S. A.
7.	,, *bremneri*	... Nigeria
8.	,, *Diphyllidium caninum*	... India
9.	,, *Hymenolepis murina*	... U. S. A.
10.	,, *Dibothriocephalus latus*	... Europe, America.

II. Man the intermediate host

1.	*Taenia echinococcus*	... Cosmopolitan.

Comparison of the liverfluke with the tapeworm

The tapeworm resembles the liverfluke in several essential characters : 1. bilateral symmetry, 2. triploblastic origin of the organs, 3 coelom filled up with parenchyma, 4. absence of skeletal, circulatory and respiratory organs, 5. branched excretory and reproductive organs, 6. hermaphroditism,

7. Presence of nerve-ring and nerve cords, 8. parasitic mode of life, 9. different types of larvae, 10. change of hosts, 11. combination of asexual and sexual modes of reproduction and 12. high reproductive potentiality.

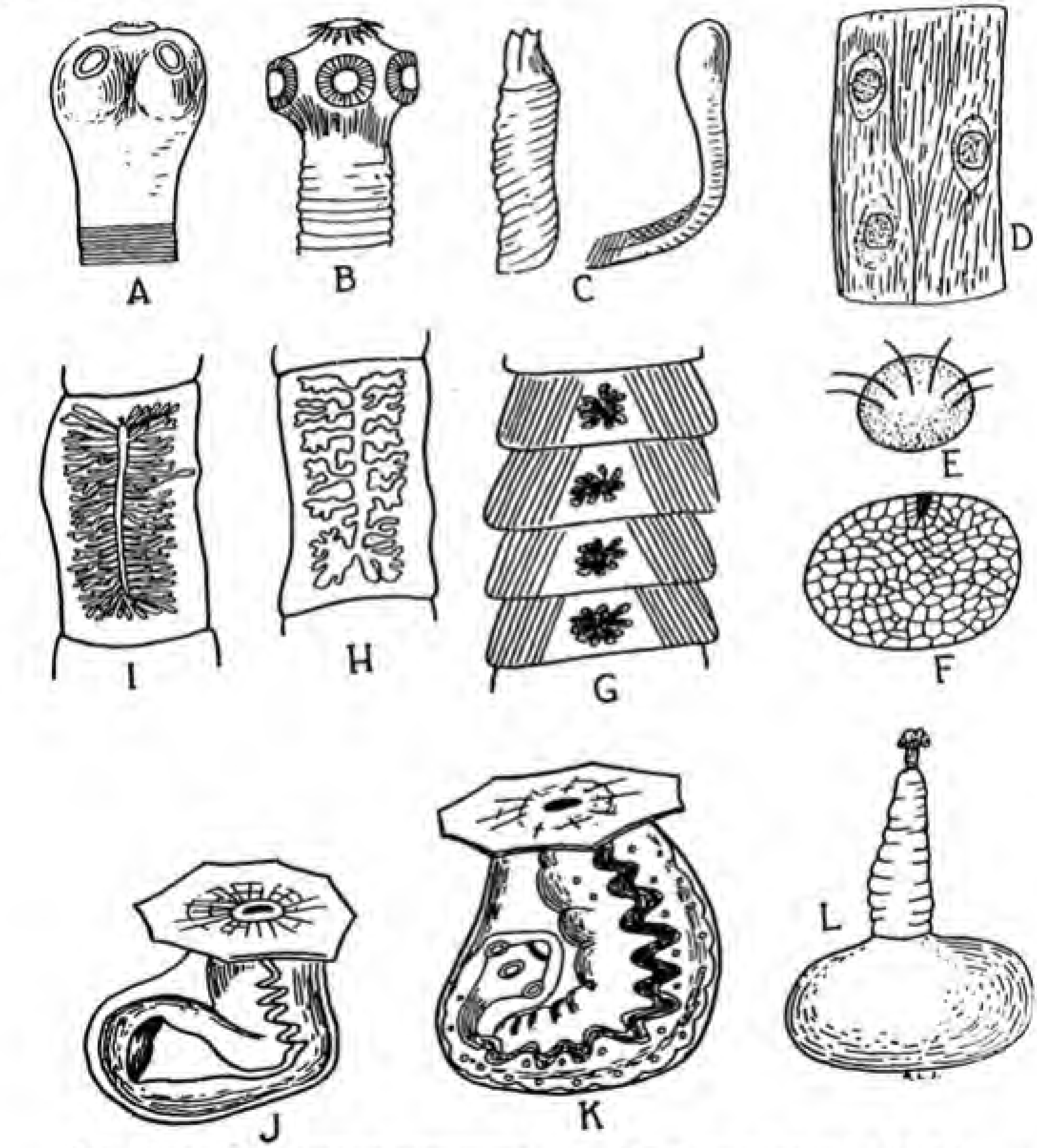


FIG. 170. Three human tapeworms. A, B & C. scoleces and I, H & G ... proglottids respectively of *Taenia saginata*, *T. solium* and *Dibothriocephalus* ... D. measly pork containing encysted embryos, E onchosphere (hexacanth), J. ... invaginated, K. proscolex with hooks and suckers, L scolex everted. (*Mod.* ... *Leuckart's Parasiten des Menscthe.s.*)

The tapeworm however also differs in a number of respects. It is in some ways better adapted than the liverfluke for an endoparasitic mode of life. The degeneration of its organization due to the parasitic life

has also correspondingly progressed far more than in the liverfluke. All the vital activities of the tapeworm are reduced to the highest level of economy and are concentrated only on two functions: excretion of metabolic wastes and maximum reproduction. Living soaked up in the digested food of its host, the tapeworm has not even the need for swallowing and digesting the food and therefore lacks an alimentary canal. The loss of the digestive tract is the height of degeneration. A tapeworm neither eats to live nor lives to eat but lives only to reproduce! The larvae of the liverfluke actively find their intermediate hosts but the tapeworm hexacanths do not even take that trouble. They are passively taken in by the intermediate host. Further, the cercariae and rediae actively migrate from one organ to another in the intermediate host but the tapeworm larva is carried passively by the blood stream to its place of encystment in the intermediate host. Truly the tapeworm leads the laziest life!

SYNOPSIS OF DIFFERENCES

LIVERFLUKE	TAPEWORM
Adult	
1. Body leaf-shaped and not partitioned into proglottids; generally 1–2 inches long.	Body ribbon-shaped, partitioned into a number of proglottids and generally several yards long.
2. No scolex.	Scolex present.
3. Only one sucker serves for attachment.	Generally four suckers and several hooks serve for attachment.
4. Mouth present.	No mouth.
5. Alimentary canal a branched tube.	No alimentary canal.
6. Excretory system opens to the outside by a single excretory pore.	Excretory system opens to the outside by paired pores.
7. Ovary unpaired.	Ovary paired.
8. Oviduct communicates with the outside through the genital aperture.	Oviduct ends as a blind uterus.
9. Ova discharged actively by the parent through the genital aperture.	Ova escape through the rupture of uterus and of the proglottid.
10 Nerve ring and two longitudinal cords.	Nerve ring and three longitudinal cords.
11. Adults in liver, blood and lungs, rarely gut of the host.	Adults in the gut of the host.

Life-History

1. The ova are discharged actively by the parent through the genital aperture.	Ova are not discharged but escape by the rupture of the uterus and the proglottid within the stomach of the intermediate host.
2. The ciliated miracidia actively swim in search of the intermediate host.	The hexacanth is not free; it is enclosed in the egg shell and is taken passively by the intermediate host.
3. The miracidia and redia actively migrate by burrowing from one organ to another in the intermediate host.	The hexacanth is passively transported by the blood stream of the intermediate host.
4. The sporocyst and redia develop respectively in the pulmonary chamber and liver of the intermediate host.	The cysticercus develops in the voluntary muscles of the intermediate host.
5. Cercariae leave the intermediate host and actively swim in search of grass on which to encyst.	The cysticercus remains encysted in the intermediate host itself and waits to be picked up by the main host.

RESUMÉ

I. Platyhelminthes

1. The Platyhelminthes are bilaterally symmetrical unsegmented flatworms, that usually have branched viscera and parenchyma filling up the coelom. Some are free living and others are parasitic.

2. They are divided into three classes: Turbellaria, Trematoda and Cestoidea.

3. The Trematoda comprise liverflukes, bloodflukes and other parasitic forms. The Cestoidea comprise tapeworms.

II. The sheep liverflukes

4. *Fasciola hepatica* infests the liver and bile ducts of sheep, goat, ox, man and various other animals and causes "liver rot". It feeds on the glycogen and the liver tissues of its hosts.

5. It is a leaf-shaped flatworm with a pair of suckers, a blind but much branched gut and well developed gonads

6. In the course of its complicated life-history, it passes through several larval forms and requires two hosts to complete the development. The miracidia larvae that hatch out from the ova voided with sheep faeces, burrow into the pulmonary chamber of fresh-water snails. In the liver of the snail, they change to sporocysts from which develop the rediae. The latter reproduce parthenogenetically and finally give rise to cercariae The cercariae leave the snail and become encysted as metacercariae on blades of grass. A sheep harbours the metacercariae while grazing. The metacercariae escape as young liverflukes in the stomach.

7. The simplicity of organization and the complexity of life-history are the direct results of an endoparasitic life.

III. **The pork tapeworm**

8. Tapeworms are mostly intestinal parasites of man and other animals. They lack an alimentary canal. The body is composed of scolex with hooks and suckers and of several proglottids. Each ripe proglottid contains a complete set of reproductive organs.

9. The ripe proglottids pass out with human faeces and are swallowed by pigs. The hexacanth embryos become encysted in the voluntary muscles of the pig. Man becomes infected by eating measely pork.

CHAPTER X

NEMATHELMINTHES

Nemathelminthes. The NEMATHELMINTHES comprise the cylindrical unsegmented roundworms or threadworms. They are triploblastic and bilaterally symmetrical. The body is protected by non-cellular cuticle. They differ from the flatworms in having a complete digestive tract, with mouth and anus. They do not also have suckers or cilia. The body wall consists of only longitudinal muscle bundles ; there are no circular muscles.

Circulatory or respiratory systems are absent and excretory organs are simple. Nervous system comprises an anterior nerve-ring, giving off six or more longitudinal nerve cords. The sexes are separate and there is no asexual reproduction.

Most roundworms are small or minute but some are several inches long.

Roundworms are mostly free-living and inhabit moist soil or fresh-water containing decomposing organic matter and rich in bacteria, which are their main food. Many aquatic species feed on algae and diatoms. Some attack roots or leaves of plants and give rise to swellings called ***galls***. Several roundworms are parasitic in various classes of animals. Man is parasitized by the following roundworms :

1. *Ascaris lumbricoides*
2. *Enterobius vermicularis*
3. *Strongyloides stercoralis*
4. *Ancylostoma duodenale*
5. *Necator americanus*
6. *Wuchereria boncrofti*
7. *Dracunculus medinensis*
8. *Trichinella spiralis*
9. *Trichiuris trichiura*

Domestic animals are also parasitized by a number of species. For example, *A. lumbricoides* attacks cattle, sheep, goat, pig, etc., in addition to man. The horse is subject to the attack of *A. equorum* and other roundworms. The dog harbours *Ancylostoma caninum*. The chicken are commonly parasitized by *Syngamus trachea*. Nearly three thousand species of roundworms are known.

Characters. The Nemathelminthes are recognized by the following characters :

1. Triploblastic, bilaterally symmetrical, unsegmented, slender, cylindrical worms with tough cuticle.
2. Alimentary canal complete, with mouth and anus at opposite ends.
3. Body wall with only longitudinal muscle fibres.
4. Body cavity a pseudocoel.
5. No organs of circulation or respiration.
6. Excretory organs simple or absent.
7. Nerve ring round the oesophagus with 6 or more nerve cords.
8. Sexes separate generally ; reproduction sexual only.
9. Gonads with ducts.
10. Fertilization internal
11. Eggs minute, with chitinous shell.

Classification

Phylum NEMATHELMINTHES

Class *NEMATODA*

Order i. ASCAROIDEA. Mouth with three lips; free-living or parasitic. Examples : *Ascaris, Heterodera, Anguillula, Mermis.*

Order ii. STRONGYLOIDEA. Oesophagus club-shaped but without bulb or valves; expanded caudal bursa in male ; parasitic. Examples : *Strongylus, Ancylostoma, Necator.*

Order iii. FILARIOIDEA. Oesophagus muscular in front and glandular behind, without bulb; parasitic, with intermediate hosts. Examples : *Wuchereria, Dracunculus.*

FIG. 171. Phylum Nemathelminthes, Order Ascaroidea : *Ascaris.* Order strongyloidea : *Ankylostoma.*

Order iv. DIOCTOPHYMOIDEA. Spiny worms with one to three rows of papillae in the mouth; caudal bursa of male rayed; parasitic, with intermediate hosts. Example : *Dioctophyme.*

Order v. TRICHINELLOIDEA. Body with the oesophageal and posterior regions distinct; ovary single; parasitic. Example : *Trichinella.*

1. ASCARIS

Bionomics and systematic position.—*Ascaris lumbricoides*, the common roundworm of man is of cosmopolitan distribution. It has been known to man from very early times and is described in ayurvedic treatises It also attacks apes, pig, boar, squirrel and sheep The roundworm of the pig is morphologically identical with that of man but physiologically distinct : the strains from the pig fail to reach maturity in man and vice versa. Its systematic position is as below:

Phylum NEMATHELMINTHES
Class *NEMATODA*
Order ASCAROIDEA
Family *Ascaridae*
Subfamily Ascarinae
Genus *Ascaris*
Species *lumbricoides*.

Structure.—The adult worms are about the size and also have the general appearance of the common earthworm, but are unsegmented. The body is long, slender, cylindrical and tapering both anteriorly and posteriorly. The body wall comprises a smooth elastic cuticle with four whitish ***longitudinal lines***. The cuticle is secreted by a subcuticular ***syncytium*** or a sheet of nucleated protoplasm without cell boundaries. Beneath the syncytium lies the single layer of longitudinal muscle coat. These muscles contract and bend the body dorso-ventrally.

The alimentary canal is a straight tube running the whole length of the body. The mouth opens at the anterior end and is bounded by three lips: one dorsal and two ventro-lateral. The lips bear ***papillae***. The mouth leads into the buccal cavity, continued behind as a muscular oesophagus for sucking the food. The oesophagus continues behind as the non-cellular intestine, for absorbing the digested food. The terminal part is the short rectum, which opens to the outside by the anus at the posterior end of the body.

The excretory system consists of a pair of longitudinal canals imbedded in the lateral longitudinal lines. These canals extend the whole length of the body and are connected anteriorly by a transverse ventral bridge, which opens to the outside by a narrow ventral duct. There are flame cells. Four large branched cells projecting anteriorly into the body cavity from the lateral lines constitute the ***phagocytic organs***. They act as filters and remove bacteria from the body fluids.

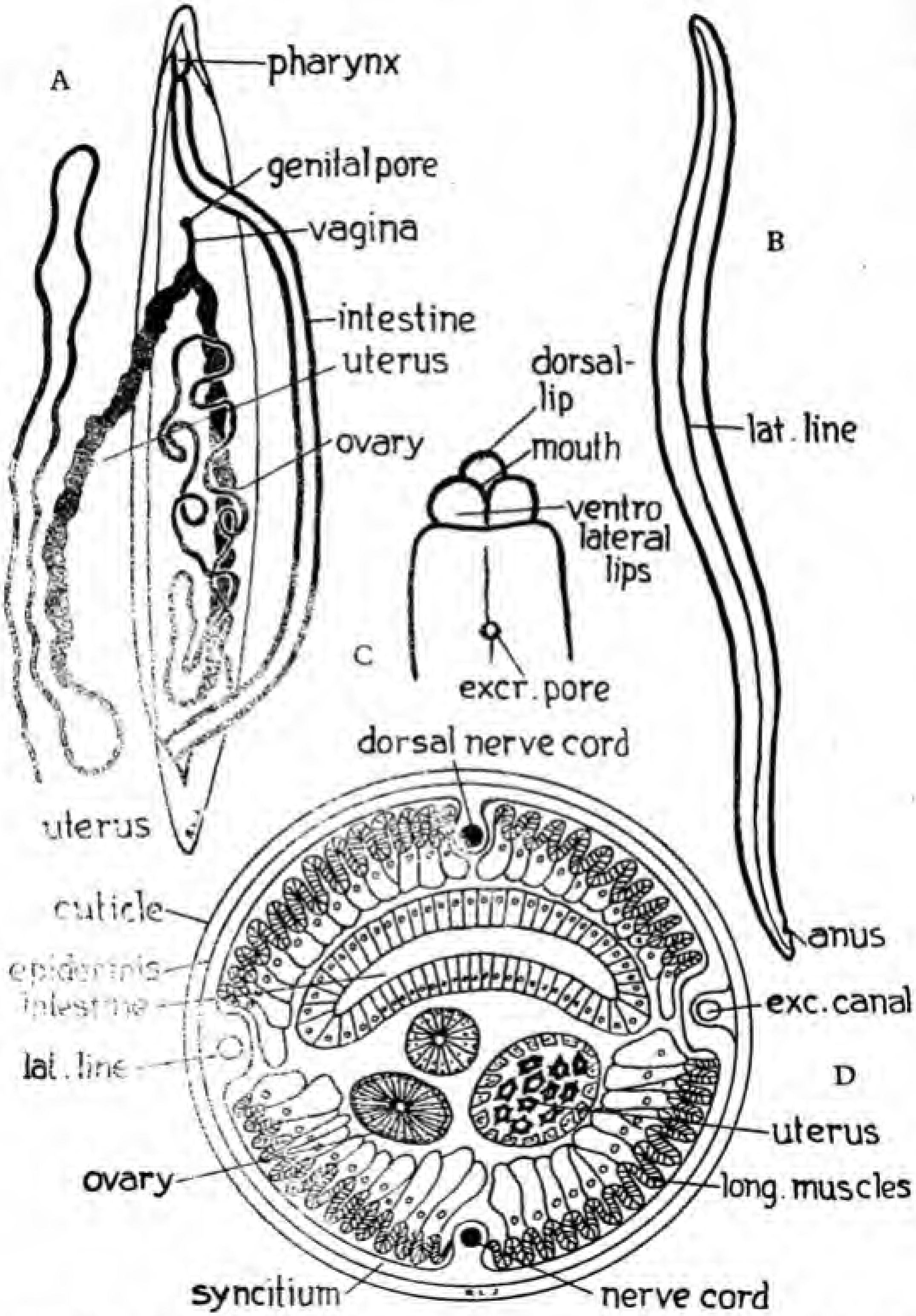


FIG. 172. Structure of *Ascaris lumbricoides*. A. Internal structure of female, B. External features. C. Anterior end, D. Transverse section of female.

The nervous system consists of a nerve-ring surrounding the oesophagus. Longitudinal nerve cords arise from this ring and run the whole length of the body. There are eight posterior nerve cords; a large median ventral, a median dorsal, two lateral and four sublateral. The longitudinal cords are connected by transverse commissures at intervals. The median and sublateral cords are motor nerves and the laterals are sensory nerves. ***Tactile papillae*** at the two extremities of the body comprise the sense organs.

The sexes are separate. The males are usually smaller than the females. The testis is a single elongate coiled tube practically filling up the body cavity. It is closed at the free end and is continuous with the vas deferens at the other end. This leads to a seminal vesicle for storing the semen. The vesicle opens into the rectum by an ejaculatory duct. The rectal opening in the male is thus not an anus but a cloacal opening. The cloaca is surrounded by a sheath containing two copulatory ***penial spicules,*** which are inserted into the vulva of the female at the time of copulation.

The female genital organs are paired ovaries connected to two uteri, which unite into a vagina. The vagina opens not into the rectum but directly to the outside by the ***vulva*** ventrally at about the anterior one-third of the length of body.

Life history.—The adults live within the intestine of the host, where the mating also takes place. The eggs are fertilized in the uterus. A single female produces nearly 250,000 eggs per day and may discharge over 27,000,000 eggs during her life. The eggs pass out of the host with its faeces. After a period of development in warm damp place, the embryos become infective. The eggs are very hardy and can withstand prolonged desiccation and cold for several years. If ingested by man or other host, the larvae hatch out in the duodenum. They burrow into the intestinal wall, penetrate lymphatic or blood vessel. They are passively carried by the blood stream to the heart, whence they reach the lungs. Rupturing the capilleries, the larvae escape into the alveoli. In the alveoli they grow and cast off their skin. In due time the larvae migrate up the bronchi and trachea into the mouth and are swallowed. On thus reaching the intestine a second time they again moult and become young worms.

Effect on the host.—The damage to the host is twofold : mechanical and physiological. A few hundred worms block the intestine and thus cause intestinal obstruction The bile duct is also frequently blocked by the worms with serious results. When very numerous the worms often wander

up into the appendix, stomach, oesophagus and even appear at the mouth and nose. The greatest damage is done by the larvae during the migration. Their passage through the lungs sets up inflammation and leads to the condition resembling pneumonia. Toxins secreted by the worms cause sickness. Finally the worms rob the host of its food.

2. HOOKWORM

Bionomics.—There are many species of "hookworms" that live in the intestine of man. They feed on the blood which they suck from wounds they make in the intestinal wall. The hookworms have no hooks but are called so because of the hook-like appearance of the subcuticular projection in the posterior end of male. The adults are about 10 mm long and are provided with cutting plates in the mouth. They attach themselves to the intestinal wall and feed on the blood, lymph and mucus, thus causing bleeding into the intestinal cavity.

The cosmopolitan species. *Ancylostoma duodenale* and *Necator americanus* are common in India.

Life history. The hookworms mate in the intestine of their host. A single hookworm produces nearly 10,000 eggs per day. The early stages of development are passed in the host and advanced eggs pass out with the faeces. The young larvae hatch in one or two days, grow and moult twice. After about a week the larvae are capable of infecting a new individual of the host. On coming into contact with the bare feet, the larvae bore through the skin and reach the veins or lymphatics. They are carried by the blood stream to the heart. Like ascaris, they reach the lungs, ascend the trachea and are swallowed. They finally reach maturity in the intestine.

Even a couple of dozens of hookworms cause so much bleeding that anaemia, lack of energy, etc. result.

3. TRICHINELLA

The trichinella worm or *Trichinella spiralis* attacks man, pig, rat and other animals and causes a disease called ***trichinosis***. The attack is characterized by pain in the abdomen, swollen muscles and fever. The worm is cosmopolitan and common in America, Europe and India.

Life history.—The females are viviparous. After copulation, the female burrows into the intestinal wall and penetrates the lymphatics. Here it gives birth to a large number of larvae. These are carried by the lymph and the blood stream to the muscles of the diaphragm, tongue, throat, eyes and ribs. They now grow and become encysted. They retain life for over ten years. The cysts become calcified after a time and the larvae die.

If within this period the flesh is eaten by a carnivorous animal, the cyst is dissolved in its stomach and the larvae escape into the intestine, grow

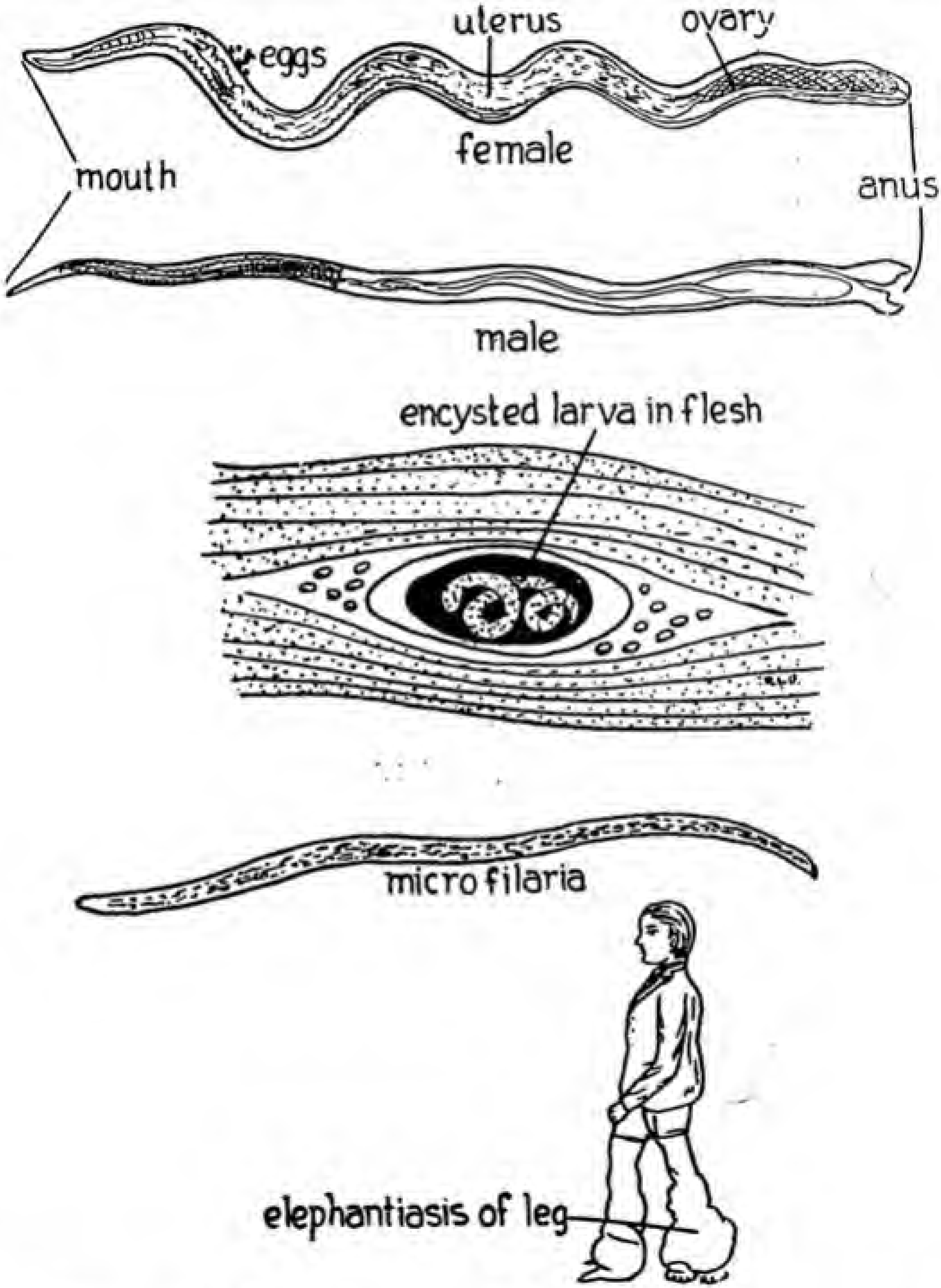


Fig. 173. A-B. *Trichinella spiralis.* A. Adults, B. Larva encysted in skeletal muscle of the host. (*Modified from Storer.*) C. *Wuchereria bancrofti*, the filaria worm that causes elephantiasis in man.

and mature into the adult. In cases of heavy infestation, the muscle degenerates and death follows by paralysis of respiratory muscles.

4. FILARIA

Bionomics.—The filaria worm, *Wuchereria boncrofti* (formerly *Filaria sanguinis*), causes elephantiasis in man in tropical and subtropical countries, including India and Ceylon. The adult worms occur in lymph glands, for example in the varico-lymphocoele of the scrotum in males. The adults obstruct the lymphatic vessels and thus produce inflammation and excessive growth of the connective tissue resulting in elephantiasis.

Life-history.—An intermediate host, usually the *Culex* mosquito (also some species of *Anopheles*,) is required for completion of the life-cycle of *Wuchereria*. A female worm gives birth to nearly one thousand larvae called microfilariae The microfilariae remain in the deeper blood vessels during the day but crowd in the capillaries of the skin at night. When a mosquito sucks blood at night, the microfilariae pass into it. In about twenty-four hours they migrate from the gut of the mosquito to the muscles of the thorax. Here they remain "quiet", undergo change of form, grow shorter and stouter. Then the larvae grow larger and again become active and move into the proboscis of the mosquito. If now the mosquito bites a man, the larvae jump off to the skin and burrow into his body. They reach a lymphatic vessel and grow to maturity.

5. GUINEA WORM

Bionomics.—*Dracunculus medinensis* or the guinea-worm is one of the most loathsome nematode parasites that attack man in Africa, Arabia, India, South America and the West Indies. In India the most heavily infested areas are Marwar, Deccan, Mysore and certain parts of the Salem district. The guinea-worm also attacks various domestic and wild animals like horse, ox, sheep, dog, cat, jackal, wolf, cheeta and leopard.

The male is extremely rare. The adult female lives in the subcutaneous connective tissue, especially of the leg. When mature, it pours out a toxic secretion, which causes a blister, about the size of a small coin on the skin (hence the name) The blister bursts and forms an ulcer. Through a hole in this ulcer, the female protrudes and if the leg is dipped under water, discharges her embryos in a milky-white stream. The female worm often measures 1000 mm long. Winding the worm on a stick, a few turns every day, when it appears through the ulcer, is the usual method of removing the guinea-worm. If during this winding, the worm gets broken, severe poisoning results, leading often to death.

Life History.—When the ulcerated part of the leg of the host is exposed to water, the anterior end of the worm is protruded out. The uterus and the body wall rupture and the young larvae escape into the water. The larva has a blunt head and a long slender tail. It seeks water-fleas (*Cyclops*), which swallow it Once within the cyclops, the larva migrates through the wall of the alimentary canal into the body cavity. Here it moults twice and becomes mature in about a month. Human infection arises by accidental swallowing of the cyclops with drinking water from tanks and wells.

6 PINWORM

Enterobius vermicularis, the common pinworm of man, especially childern, is of cosmopolitan occurrence. The adults measure about 8 mm long and inhabit the small intestine, caecum, appendix and colon. The gravid females migrate down to the anus at night and cause intense itching. The worms burst and the eggs are scattered on the fingers and clothing while scratching. If the eggs are swallowed re-infestation takes place.

OTHER NEMATODES

Loa loa or the eyeworm is about an inch or so long and lives in the muscles of the eye-lid, in the conjuctiva, anterior chamber of the eye and various other organs. The parasite also wanders about the body and is often seen beneath the skin It gives rise to creeping sensation and temporary swelling of the parts, redness, etc. The larvae develop in the salivary glands of the eye-fly, *Siphonella*, which is probably a vector.

Trichiuris trichiura or the whipworm is one of the common parasites of man, distributed nearly all over the world. The worms usually live in the caecum and occasionally in the vermiform appendix and colon or rarely in small intestine.

RÉSUMÉ

1. The Nemathelminthes are cylindrical unsegmented worms with complete digestive tract. Some are free but many are parasites.

2. They are classified into Ascaroidea, Strongyloidea, Filarioidea, Dioctophymoidea and Trichinelloidea.

3. *Ascaris lumbricoides*, a cosmopoliton roundworm, parasitizes man, apes, pig, boar, sheep and squirrel.

4. The adults inhabit the small intestine of the host. The eggs are discharged with the faeces of the host. The worm does not require an intermediate host but the larvae become infective after developing in warm damp places. When ingested by the host, they burrow through the gut and are carried by the blood stream to the lungs, thence to the mouth and are swallowed again. Now they reach maturity in the intestine.

5. Other important parasitic Nematodes include the hookworms, *Trichinella*, *Wuchereria* that causes elephantiasis, *Dracunculus* the guinea-worm, the pin-worm, *Loa loa* and the whipworm. Some of these complete their development in an intermediate host.

CHAPTER XI

ANNELIDA

Annelida. The phylum ANNELIDA includes the segmented worms. The body is elongate, bilaterally symmetrical and divided into a number of similar ***segments*** or ***metameres***, each with paired coelom pouches, nerve ganglia and nephridia. The alimentary canal is complete and is surrounded by a distinct perivisceral coelom. The mouth is at the anterior end and the anus at the posterior. There is often a closed circulatory system. The nervous system consists of a pair of cerebral ganglia on a circumpharyngeal ring, which is connected ventrally to a double ventral nerve cord. The nerve cords run the whole length of the body and are connected to paired ganglia in each metamere. Many have rod-like chitinous appendages that are used as locomotor organs.

The annelid worms inhabit damp soil, fresh-water, sea or sea-shore. Many are free-living, but a few live in tubes; some are parasitic. They differ sharply from the flatworms and the roundworms in 1. the segmentation of the body, 2. possession of appendages, and 3. in having a distinct coelom surrounding the alimentary canal. The segmentation of the annelid worms differs from the proglottids of the tapeworms in *not* arising as buds; the segments are partitions of a single animal. The annelida are of world-wide distribution. Nearly 7000 species of segmented worms are known.

Characters. The Annelida are recognized by the following characters :

1. Triploblastic, bilaterally symmetrical and metamerically segmented.
2. Outer surface of body covered by columnar epithelium with gland and sensory cells.
3. Body wall lined with longitudinal and circular muscle fibres.
4. Appendages of chitinous setae, fleshy tentacles and parapodia.
5. Alimentary canal complete.
6. Closed blood vascular system of dorsal longitudinal vessel with segmental branches.
7. Blood plasma with haemoglobin in solution and colourless corpuscles.
8. Excretory system of nephridia in each segment.
9. Nervous system with paired cerebral glanglia and double nerve cords ventrad of the alimentary canal with segmental ganglia and nerves.
10. Sexes united or separate.
11. Reproduction by budding in some, sexual in others.
12. Development direct or with trochophore larva undergoing metamorphosis.

Classification

Phylum ANNELIDA

Class 1. ARCHIANNELIDA. Marine worms with internal segmentation. Example: *Polygordius.*

Class 2. POLYCHAETA. Marine worms with segmentation internal and external; segments with parapodia that bear many setae; sexes separate; head with tentacles. Examples: *Nereis, Aphrodite* sea-mouse, *Arenicola* lobworm.

Class 3. OLIGOCHAETA. Fresh-water or soil-inhabiting earthworms, with internal and external segmentation; no head or parapodia; few setae. Examples: *Megascolex, Pheretima, Lumbricus.*

Class 4. HIRUDINEA. Leeches with suckers but no tentacles, parapodia or setae; 34 segments externally subdivided into numerous annuli. Examples: *Hirudo, Hirudinaria.*

Class 5. GEPHYREA—Marine sand-worms without segmentation or parapodia; with retractile proboscis or tentacles. Examples: *Bonellia, Sipunculus.*

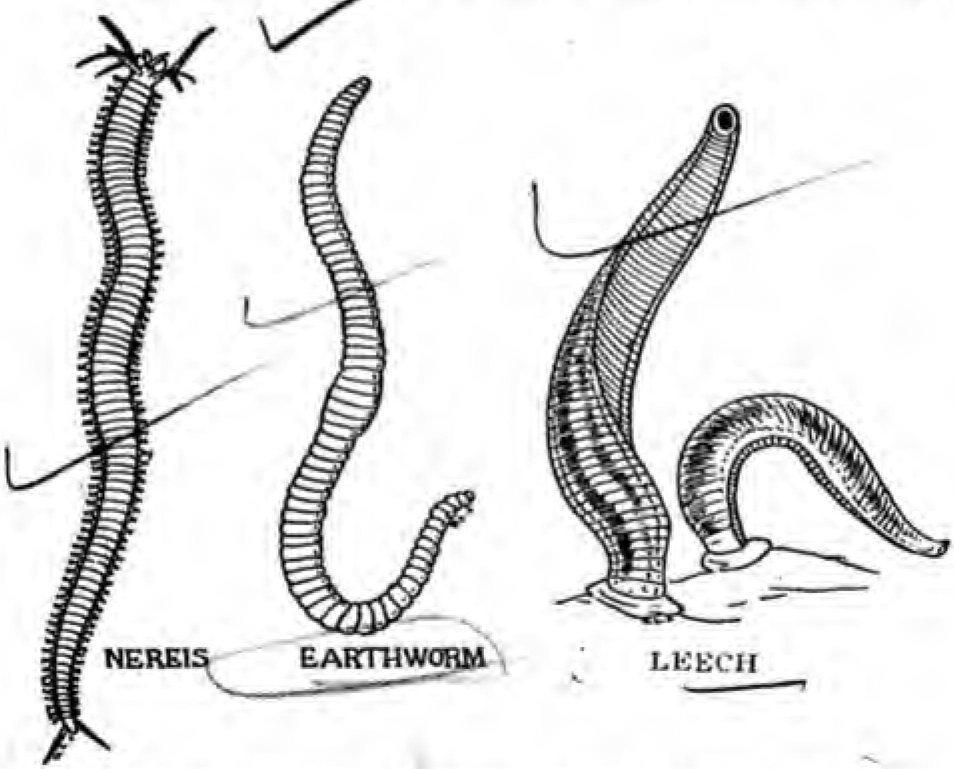


FIG. 174. Phylum Annelida. Class Polychaeta: *Nereis* is a common marine bristle worm Class Oligochaeta: Earthworms. Class Hirudinea: Leeches are blood-sucking ectoparasites.

OLIGOCHAETA

The OLIGOCHAETA are segmented worms that have no parapodia or well-marked head with tentacles. They are terrestrial and fresh-water inhabitants. A collar-like glandular ***clitellum*** is present near the anterior end of the body for secreting a cocoon for eggs. The sexes are united;

development without metamorphosis. The setae are few. Nearly 3000 species of oligochaete worms are known. They are classified as below:

Class OLIGOCHAETA

Order 1. MICRODRILI. Aquatic worms with few segments, commonly reproducing asexually. Examples: *Tubifex*, *Chaetogaster*.

Order 2. MEGADRILI. Terrestrial large worms; reproduction sexual. Examples: *Megascolex*, *Pheretima*, *Lumbricus*.

1 THE EARTHWORM

Bionomics and systematic position.—The earthworm is common during the rains. Different species inhabit different habitats: some occur in moist garden soil, others in soil wetted by drains and so on. They

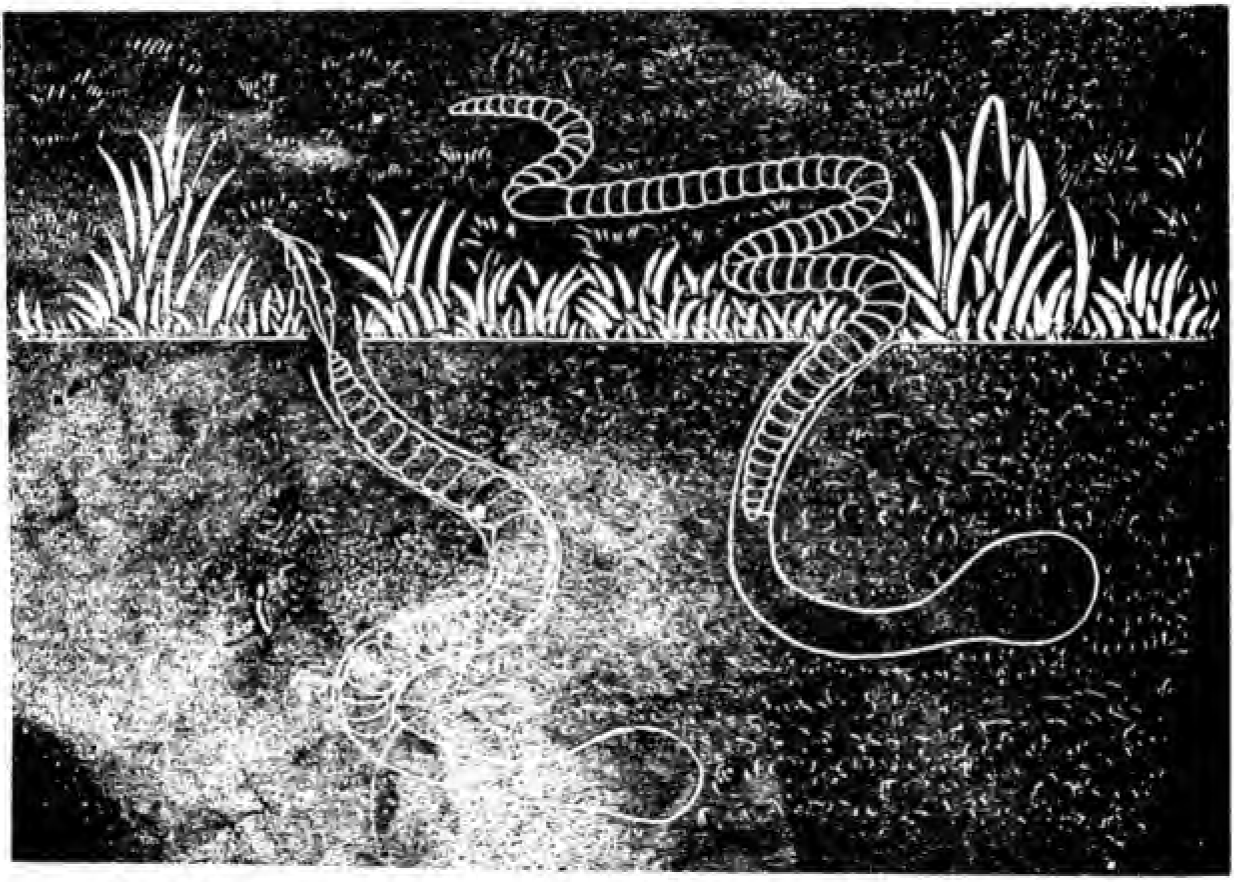


FIG. 175 Earth[illegible] burrows in moist soil. They spend the daytime in their burrow[illegible] on the surface at night to hunt for food and meet friends. They [illegible] burrow bits of leaves on which they feed, one end of the body remain[illegible] burrow and facilitates quick withdrawal if danger threatens.

mostly live in burrows in moist soil, rich in organic matter, but cannot live in dry regions. Very often the earthworm burrows as deep as 6 ft but mostly the burrows extend to a depth of two feet. The earthworm generally spends the daytime in its burrow but comes out on the

surface during the night. After a heavy rain the earthworms come out of their burrows to the surface in large numbers. This has given rise to the popular idea that they fall from the sky with the rain. Hence the earthworms are called *Regenwurm* or " rain-worm " in Germany.

Most earthworms are small. A few are less than one millimetre. The giant earthworms like *Rhinodrilus fafneri* from South America and *Megascolides australis* from Australia reach 10 ft in length and an inch in diameter.

There are several species of earthworms in India. Of these *Megascolex mauritii* (formerly *Lampito mauritii*) and *Pheretima posthuma* are generally selected as types for study. Their systematic position is as shown below:

Phylum ANNELIDA
  Class *OLIGOCHAETA*
    Order MEGADRILI
      Family *Megascolecidae*
        Subfamily Megascolecinae
          Genus 1. *Megascolex*
            Species *mauritii*.
          Genus 2. *Pheretima*
            Species *posthuma*.

17-19

Megascolex mauritii is slightly larger than *Pheretima posthuma*. It is very widely distributed in India, Ceylon, Malaya and elsewhere. *Pheretima* is common in North India.

External features.—The body of the earthworm is elongate and cylindrical. It is divided by transverse furrows into a number of ***segments*** or ***metameres*** (also called ***somites***), one behind the other. There is no distinct head. The mouth is at the anterior end and is covered by the ***prostomium*** or a fleshy hood-like lobe of the ***peristomium*** or the first segment of the body. A slit-like anal opening is at the posterior end of the body. Counting from the front, the fourteenth, fifteenth and the sixteenth segments are swollen like a collar round the body; this is the ***clitellum***. The clitellum is composed of glandular cells that secrete a cocoon for the eggs.

A single ***female genital pore*** is found ventrally on the fourteenth segment. A pair of ***male genital*** pores open ventrally on the eighteenth segment. Paired ***copulatory papillae*** occur ventrally on the seventeenth and ninteenth segments. In the intersegmental grooves between fifth and and sixth, sixth and seventh, seventh and eighth, and eighth and ninth there

are four pairs of ***spermathecal pores***. The ***dorsal pore*** of the coelom opens in the median dorsal line in the intersegmental grooves from the twelfth segment backwards to the last. Minute ***nephridiopores*** are scattered all over the body. Each segment bears fine rod-shaped ***setae*** (also called chaetae) which are the locomotor organs of the earthworm. Each seta is like an elongate S, blunt and swollen basally and pointed at the free end.

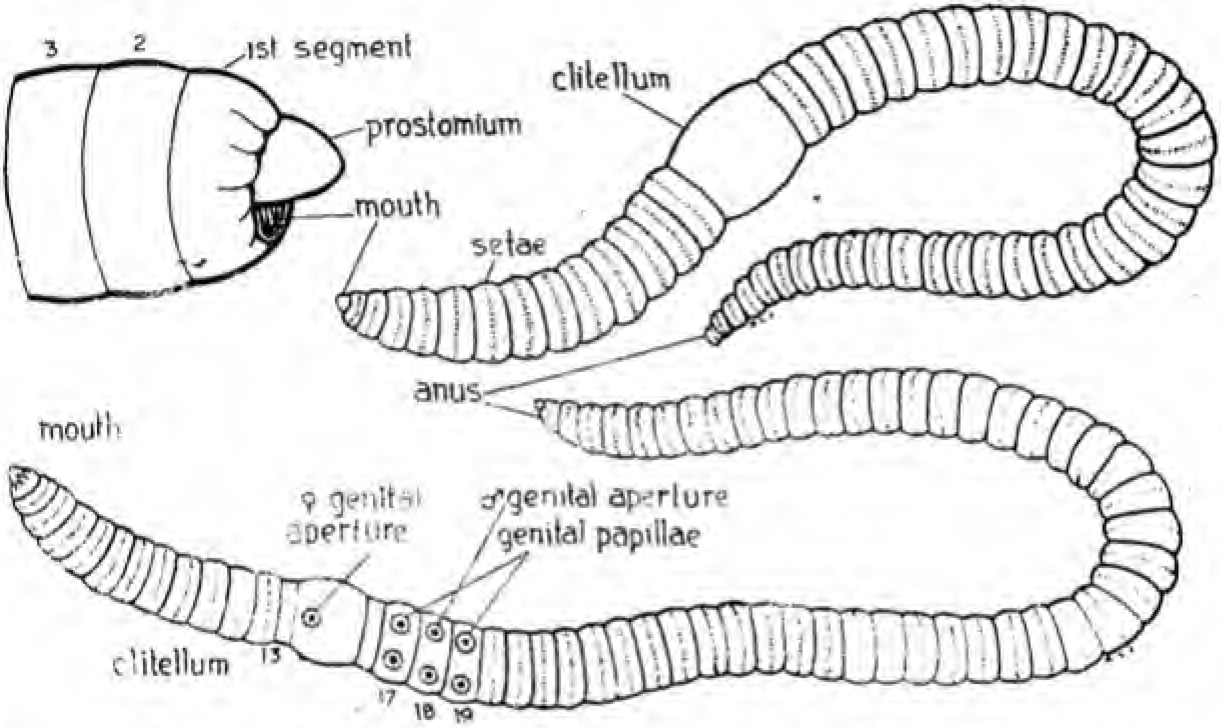


FIG. 176. External features of *Pheretima posthuma*. Dorsal view above and ventral view below. Anterior end highly enlarged at top left.

The body wall is composed of an outer cuticle, an epidermis, connective tissue, circular and longitudinal muscles and the peritoneum. The cuticle is non-cellular and finely striated. The epidermis comprises gland cells that secrete a slimy secretion, supporting cells and sensory cells. The circular muscles constitute a continuous sheath and the longitudinal muscles form parallel bundles the whole length of the worm. The peritoneum surrounds the coelom. The body cavity is divided by transverse ***septa*** to correspond with the external segmentation.

Digestive system.—The mouth leads into the buccal cavity in segments one to three. A pear-shaped muscular pharynx lies in segments three and four. The roof of the pharynx is swollen as the ***pharyngeal bulb***. The side wall of the pharynx projects into the pharyngeal cavity as the ***pharyngeal shelves***. The oesophagus extends from the fourth segment

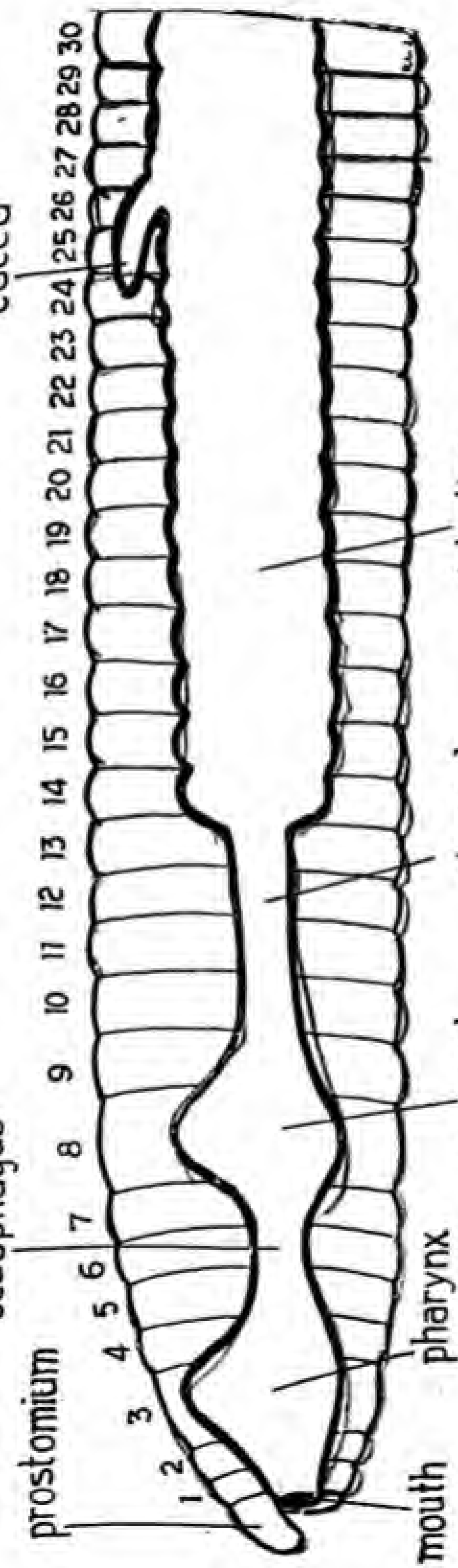


FIG. 177. Alimentary system of *Pheretima posthuma* in lateral view. (Diagramatic).

14 — F S
18 — M S
17–19 — P
4-5
5-6
6-7
7-8

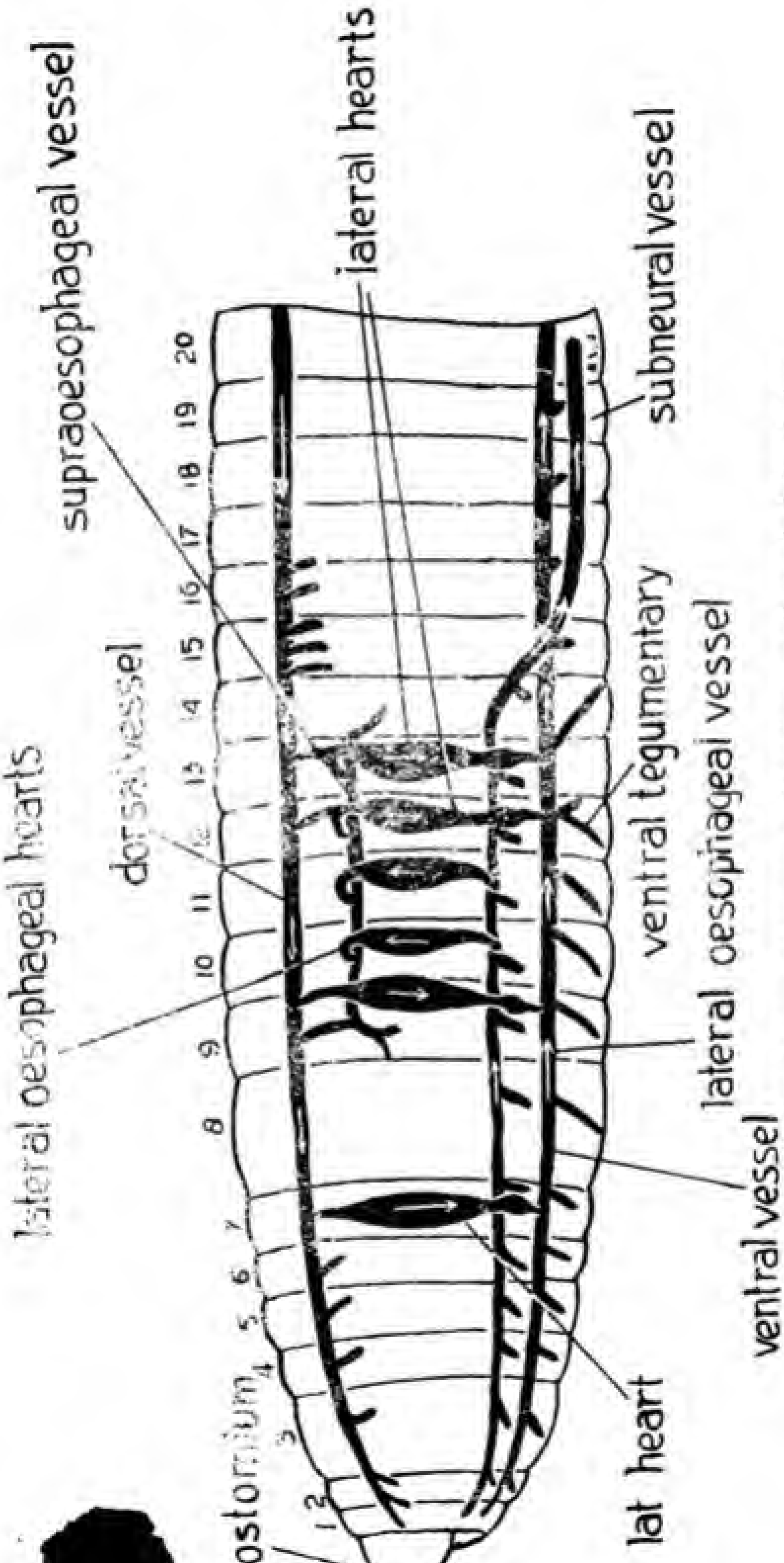


FIG. 178. Blood vascular system of *Pheretima posthuma* in lateral view.

to the seventh. In the eighth segment lies a stout muscular ***gizzard***. The gizzard masticates the food. Behind the gizzard is the stomach, which extends from the ninth to the fourteenth segment. The entrance and exit of the stomach is guided by sphincters. The wide thin-walled intestine runs from the fifteenth segment to the anus. In the twenty-sixth segment a pair of short ***intestinal caeca*** run forward from the intestine. Behind this region, the mid-dorsal wall of the intestine projects into its cavity as the ***typhlosole***, up to about twenty-five segments before the anus. Behind the typhlosolar region, the part of the intestine is called rectum.

Circulatory system.—Like the frog, the earthworm has a system of closed blood vessels in which red blood flows. There are however no red blood corpuscles ; the haemoglobin is dissolved in the plasma itself.

The circulatory system comprises 1. five longitudinal trunks with their commissures and branches, and 2. four lateral hearts. The five longitudinal trunks are (*i*) dorsal vessel, (*ii*) ventral vessel, (*iii*) supra-oesophageal vessel, (*iv*) lateral oesophageal vessel, and (*v*) subneural vessel.

The ***dorsal vessel*** is the largest blood vessel and runs the whole length of the body above the alimentary canal in the median dorsal line It exhibits peristaltic contractions from behind forward. In each segment behind the fifteenth (*i. e.* in the intestinal region) two pairs of ***dorsal intestinal*** vessels from the intestine open into it. A pair of ***commissural*** vessels from the subneural vessels open into it in the posterior part of each segment behind the fifteenth. In each segment, the dorsal vessel has a pair of valves that permit the flow of blood forward. In segments anterior to the intestine the dorsal vessel does not receive the dorsal intestinal and the commissural vessels. Near the anterior end, the dorsal vessel divides into three branches supplying pharynx and buccal cavity.

The ventral vessel extends from the second segment to the posterior end of the body. The ventral vessel does not have valves and the flow of blood is from front backward. In each segment it gives off a pair of ***ventro-tegumentary vessels*** to the body wall, septa and nephridia and a median ***ventro-intestinal*** vessel to the intestine.

The ***lateral oesophageal vessels*** are paired vessels running one on either side of the oesophagus. They are formed by the union of the branches from the body wall, septum, seminal vesicles, nephridia, etc. In the fourteenth segment the lateral oesophageals of the [illegible] bend downward to meet and fuse in the mid ventral line into the [illegible]*ural vessel*. This vessel runs ventrad of the nerve cord to the posterior end of the body.

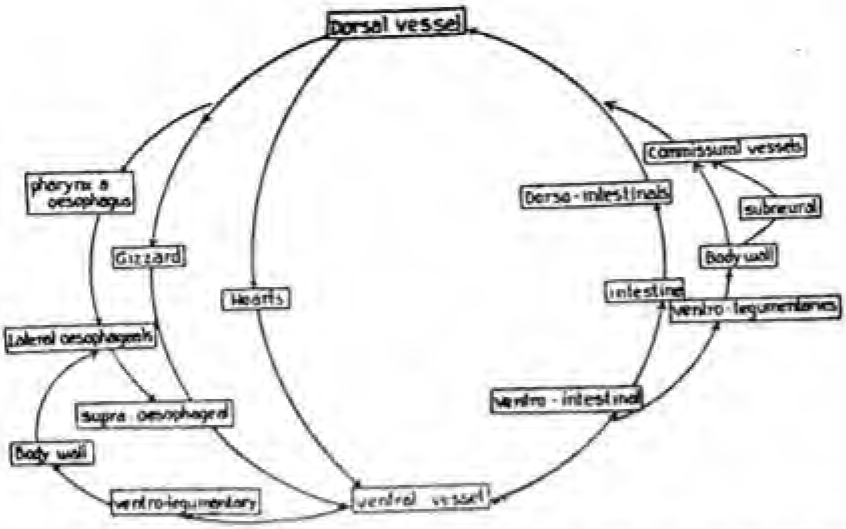


FIG. 179. Diagram of circulation of blood in *Pheretima posthuma*.

In each segment it receives a pair of branches from the integument and is connected with the dorsal vessel by the commissural vessels. The blood flows from the front backward.

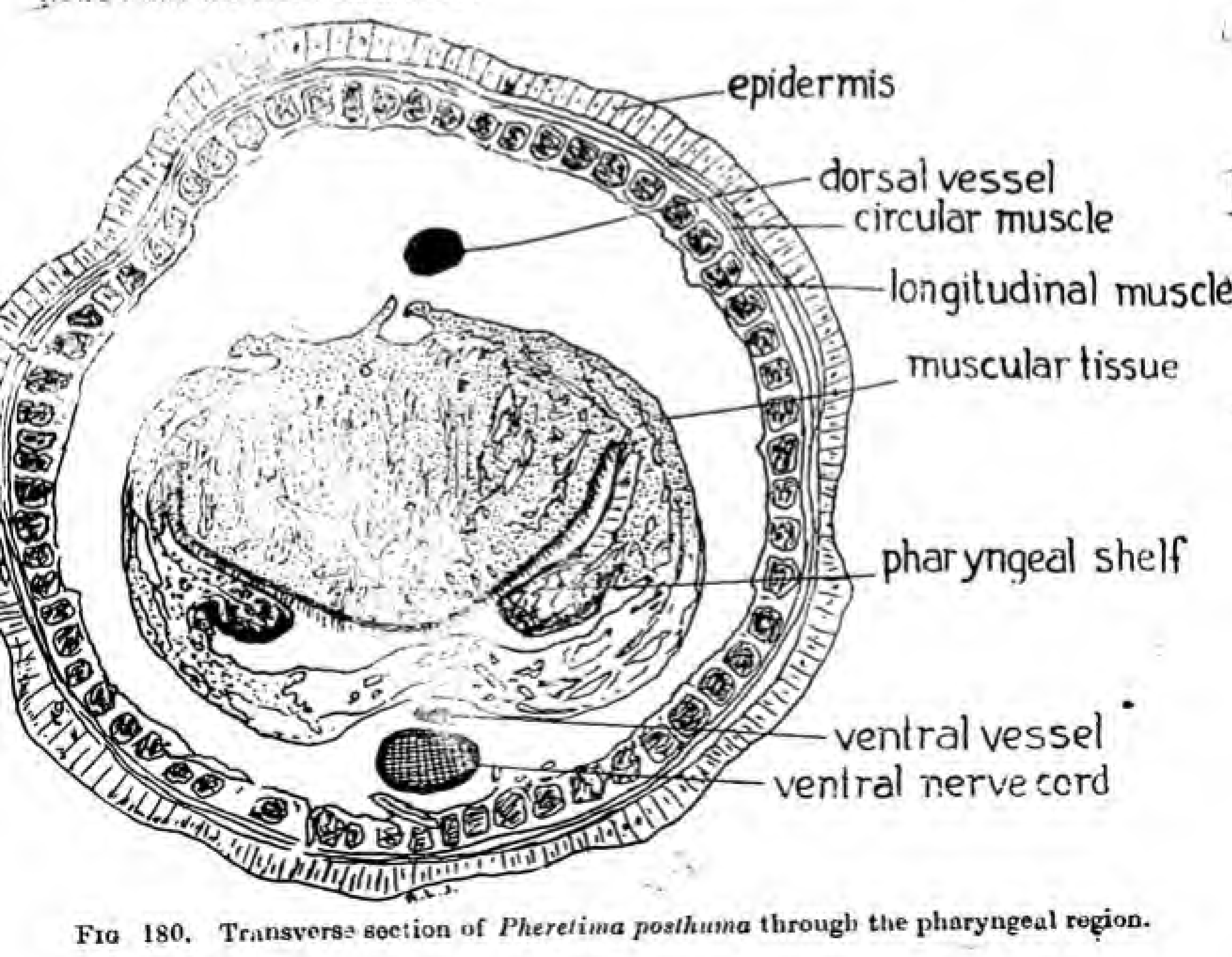


FIG. 180. Transverse section of *Pheretima posthuma* through the pharyngeal region.

The ***supra-oesophageal*** vessel lies bewteen the dorsal vessel and the esophagus and is thus confined to segments nine to thirteen. The supra-oesophageal is connected as below: A pair of hearts connect it to the

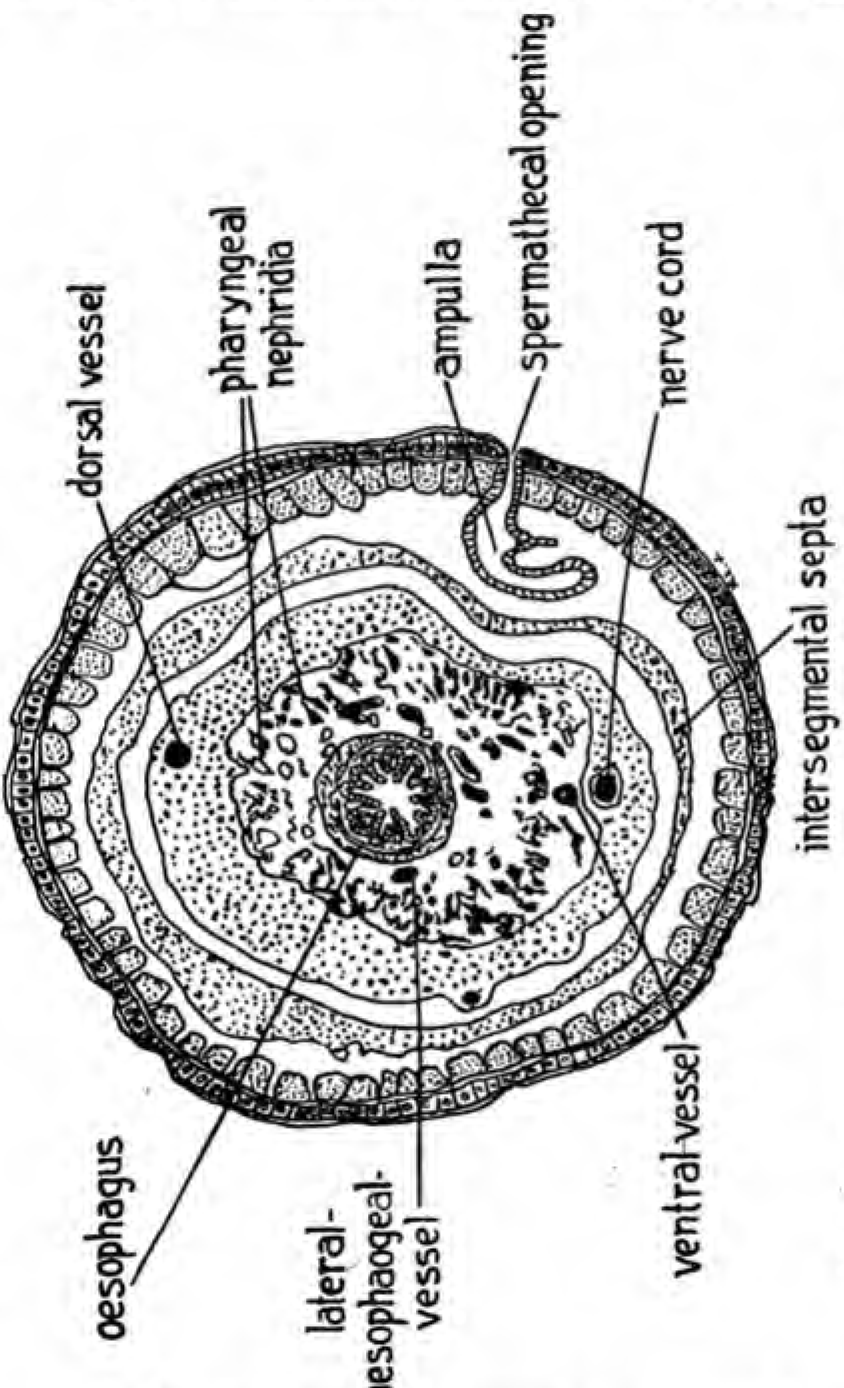


FIG. 181. Transverse section of *Pheretima posthuma* through the region of spermatheca.

lateral oesophageal in the tenth and eleventh segments. A larger pair of hearts connect it to the lateral oesophageal and to the dorsal vessels in the twelfth and thirteenth segments.

In the seventh, ninth, twelfth and thirteenth segments a pair of ***lateral hearts*** connect the dorsal and ventral vessels. Each heart pulsates from above downward and thus drives the blood from the dorsal into the ventral vessel. The lateral hearts of the twelfth and thirteenth segments communicate above with the supra-oesophageal vessel also. In the

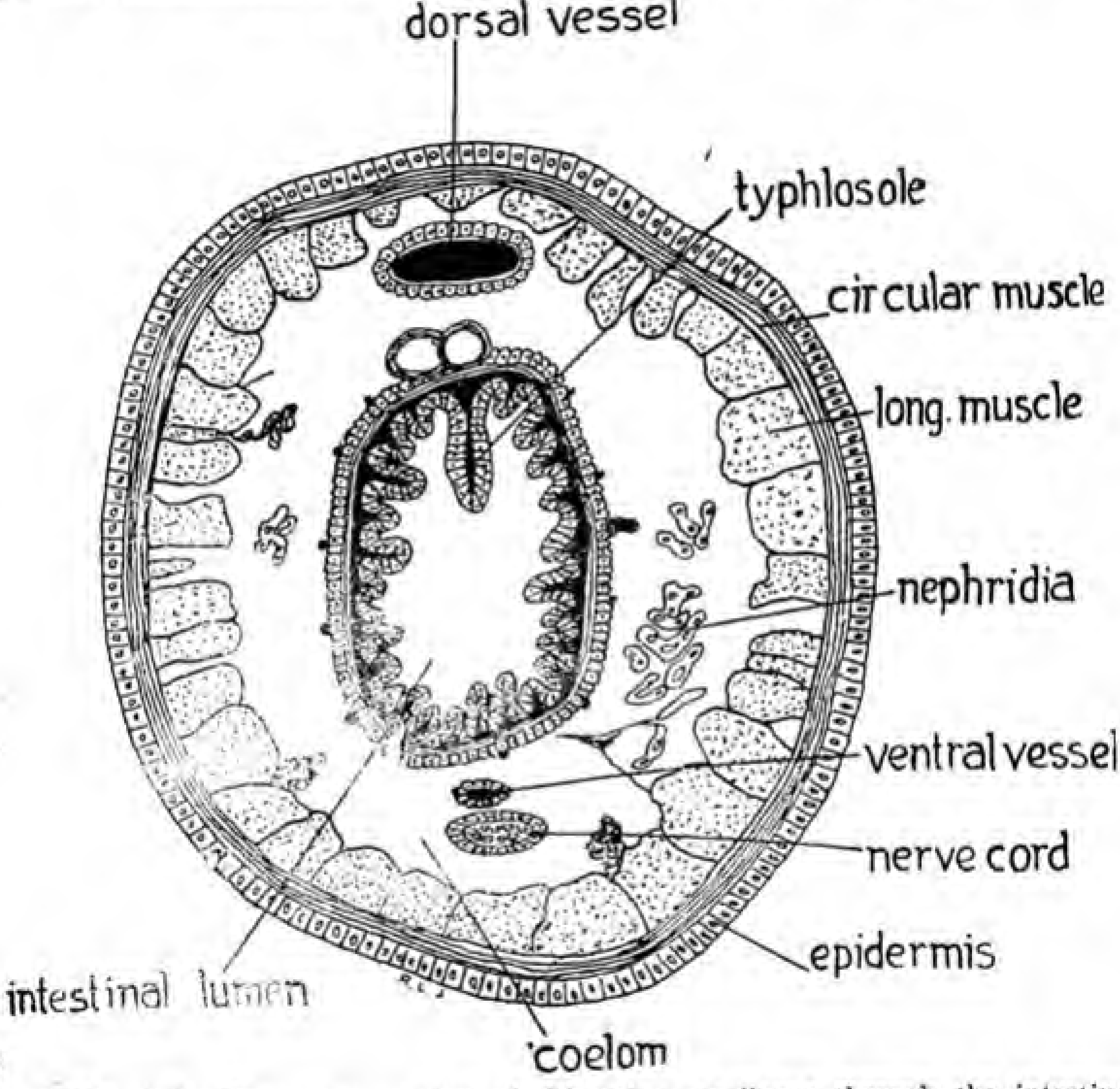


FIG. 182. Transverse section of *Pheretima posthuma* through the intestinal region.

tenth and eleventh segments a pair of ***anterior loops*** connect the lateral oesophageal and the supra-oesophageal vessels. The blood flows through these anterior loops or ***lateral oesophageal hearts*** from the lateral oesophageal vessel to the supra-oesophageal vessel. The course of circulation of blood is represented diagrammatically in Fig. 179.

Excretory system.—The excretory organs of the earthworm are the ***nephridia***. A typical nephridium is a coiled tube that occupies parts of

It excavates its burrows by the pushing away of the soil on sides in loose type of soil, but in compact soil, they have actually to swallow a lot of it and throw on the ground above.

Natural Enemies.—The earthworm has numerous natural enemies. Birds, frogs and other small animals eat large numbers of earthworms. It is also parasitized by the larvae of certain insects. The Sporozoa *Monocystis* and *Nematocystis* are common parasites of earthworms. Certain Nematodes also attack them. Bacteria take a heavy toll of the earthworms.

Relation to man.—The earthworms are of great economic importance to man. They are useful to us both directly and indirectly. All over the world they are used as baits for fish. In China and Japan the earthworms are to this day eaten or are used in various fancy medicines.

By opening up the ground and facilitating the aeration of the soil, the earthworms actually plough the earth for the farmer. They increase the fertility of soil by burying leaves and thus helping the formation of humus. When they burrow, they add nitrogenous excretory products that form important plant food. The grinding of the soil in the gizzard constitutes another kind of "cultivation". It has been estimated that the earthworms annually turn up nearly eighteen tons of soil per acre of field. In thus spreading out the mud, they cover seeds of plants and facilitate their germination.

The earthworms act as intermediate hosts for parasites of domestic animals. For example the tapeworm of chicken, the lung nematode of pigs, etc., are transmitted by them.

HIRUDINEA

The Hirudinea comprise the leeches with thirty-four body segments, that are superficially constricted into a number of annuli. Oral and posterior suckers and a clitellum are present but parapodia and setae are absent. The class resembles the Oligochaeta in the possession of clitellum, hermaphroditism, in producing egg cocoons and in the absence of tentacles and parapodia but differs in lacking setae.

The class is subdivided as below :

Class HIRUDINEA

Order 1. ACANTHOBDELLIDA. Without proboscis, jaws or anterior sucker; coelom segmented; setae present on segments II-IV. Parasitic on fish. Example : *Acanthobdella* from Siberia.

Order 2. RHYNCHOBDELLIDA. Protrusible proboscis present; with or without anterior sucker; jaws absent; marine. Examples : *Piscicola*, *Glossiphonia*.

Order 3. GNATHOBDELLIDA. Three chitinous jaws and anterior and posterior suckers present but no proboscis. Examples : *Hirudo*, *Hirudinaria*

2. LEECH

Bionomics and systematic position.—Leeches are mostly tropical animals that inhabit fresh-water. Some live in the sea and a few are terrestrial and live in the moist places. They are mostly nocturnal creatures that live by scavenging, predating or parasitizing. Some leeches devour dead animals and some hunt for small worms, molluscs and insect larvae. The majority are blood-sucking parasites on various animals like fishes, reptiles and mammals. A leech sucks enormous quantities of blood and stores it in the large caeca of the gut, to be digested slowly. A single feeding is enough for four or five months.

Leeches are very widely distributed and have been known from very early times. They are mentioned in Chinese literature. The Egyptians, Arabs and Persians were familiar with them. Various kinds of leeches are described and instructions for blood-letting are given in *ayurvedic* treatises. Leeches have been used from time immemorial for ***phlebotomy*** or drawing blood from inflamed parts but their use has now fallen off. Several species of blood-sucking leeches are known. *Hirudo medicinalis* is the best known in Europe and America and *Hirudinaria granulosa* is the most common species in India.

Phylum ANNELIDA
  Class *HIRUDINEA*
    Order GNATHOBDELLIDA (formerly Arhynchobdellida)
      Family *Hirudidae*
        Subfamily 1. Haemadipsinae
          Genus *Hirudinaria*
            Species *granulosa* (Indian leech).
        Subfamily 2. Hirudinae
          Genus *Hirudo*
            Species *medicinalis* (European leech).

Structure.—The body of the leech is elongated, depressed, darker above and marked in a characteristic pattern. It is moist and slimy. There are thirty-four segments and each segment is superficially constricted by transverse furrows into a number of ***annuli***. The prostomium and the first few segments are modified into an anterior sucker, with the mouth in its centre. A larger circular posterior sucker composed of seven segments forms a powerful organ for attachment and locomotion. The anus opens dorsally at the base of the posterior sucker. Seventeen pairs of minute nephridiopores open ventrally from the VI to XXII segments. The genital apertures are median ventral openings—the female opening one segment behind the male,

two successive segments. It consists of a pre-septal ciliated nephridial funnel or ***nephrostome*** in one segment, continued behind by a short neck that elongates into the coiled body of the nephridium in the segment behind. Nephridia are absent in the first and second segments.

The nephridia of *Pheretima* differ from this type and are of three kinds : 1. integumentary, 2. pharyngeal, and 3. septal.

The ***integumentary*** nephridia are the smallest and occur in the body wall. There are about two hundred of these in each segment. They open to the exterior by minute ***nephridiopores*** on the surface of the body.

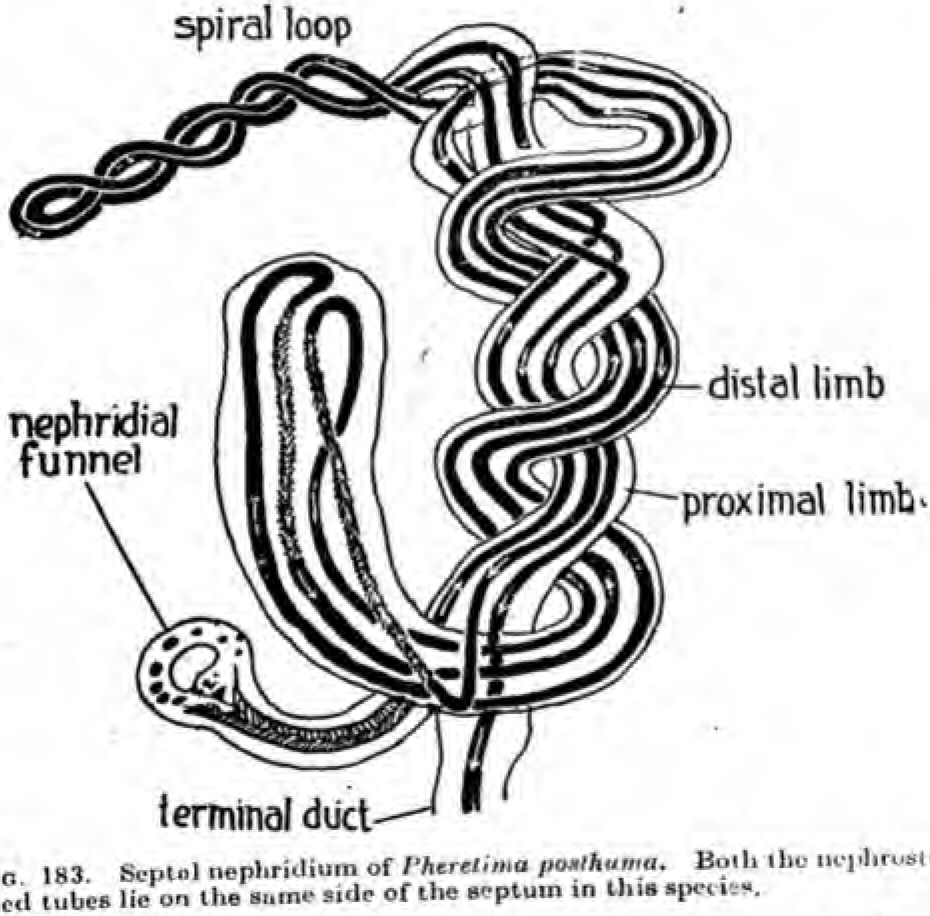


FIG. 183. Septal nephridium of *Pheretima posthuma*. Both the nephrostome and the coiled tubes lie on the same side of the septum in this species.

The ***pharyngeal*** nephridia are paired tufts of a number of nephridia in the fourth, fifth and sixth segments on either side of the alimentary canal. The ends of the tubes of the nephridia unite into three pairs of long ducts. The ducts run forward on either side of the nerve cord to open into the gut. Both the pharyngeal and integumentary nephridia lack the nephrostome.

The ***septal*** nephridia (Fig. 183) are the largest and occur in four rows on the septa in each segment from the sixteenth backward. Two rows lie on the anterior side and two rows on the posterior side of each septum. Each consists of the nephrostome, a short neck and a coiled body. The body comprises a first ***straight tube*** followed by a ***looped*** part that ends in the ***terminal nephridial duct***. The terminal ducts open into a pair of ***septal excretory canals*** that end in a pair of ***supra-intestinal ducts.*** These ducts extend from the fifteenth segment to the posterior end of the body. In each segment the ducts send out a tube opening into the intestine.

The nephridia remove the wastes from the blood and from the coelomic fluid. The pharyngeal and septal nephridia discharge into the gut, where the water is re-absorbed and the wastes pass out with the faeces.

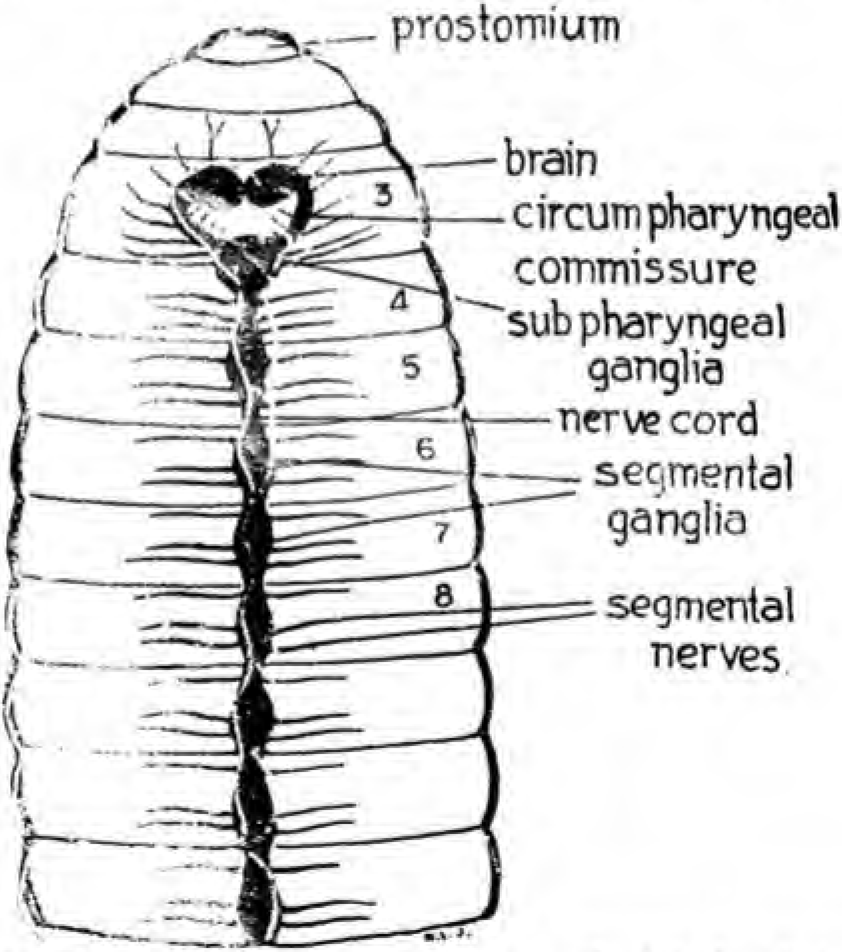


FIG. 184. Nervous system of *Pheretima posthuma* in dorsal view.

Nervous system.—The nervous system of the earthworm lies for the most part ventrally to the alimentary canal. It comprises a nerve cord extending from the fourth to the anal segment and connected anteriorly to the brain.

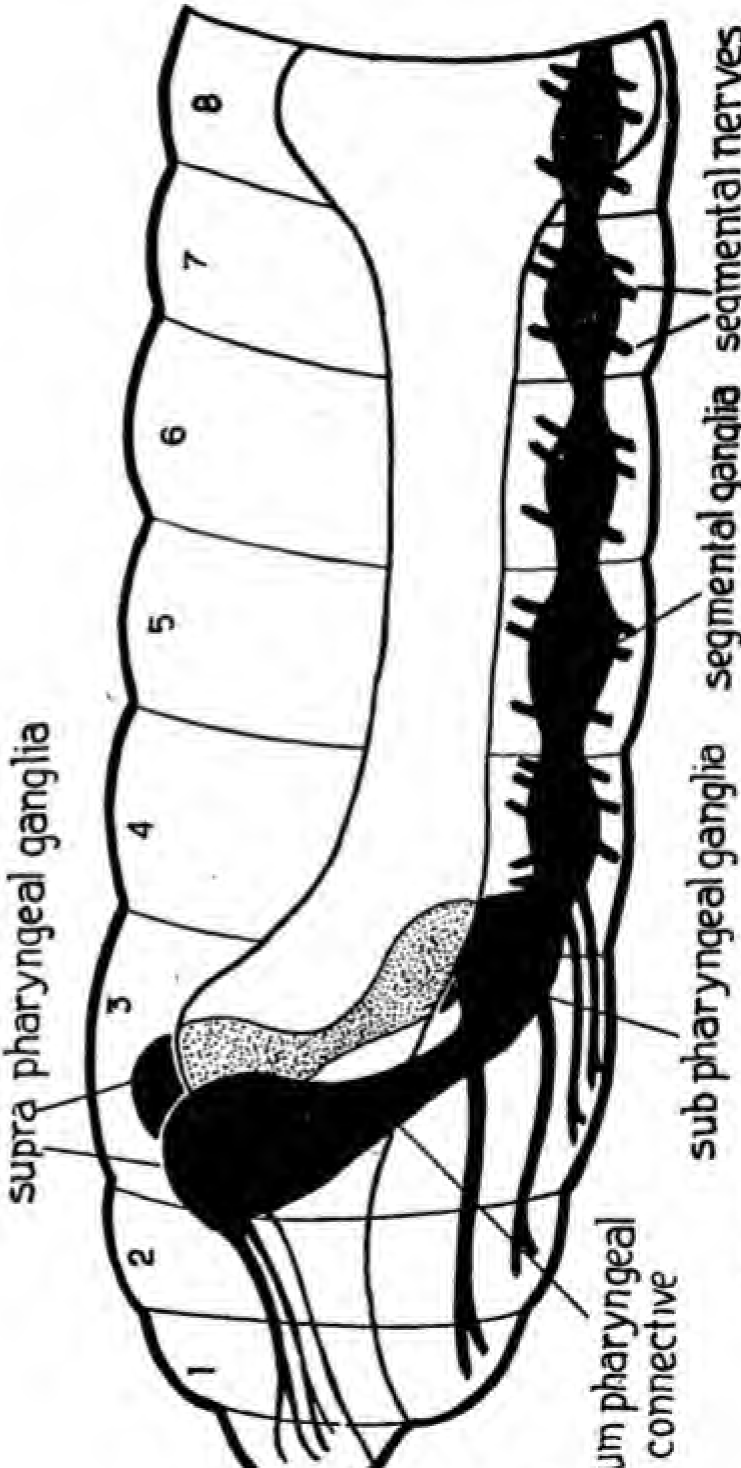


FIG. 185. Nervous system of *Pheretima posthuma* in lateral view. (Diagrammatic.)

The brain is composed of a pair of ***suprapharyngeal ganglia*** lying in the third segment above the pharynx. From these ganglia extend two ***circumpharyngeal connectives***, one on either side of the pharynx, downward and backward to the paired ***subpharyngeal ganglia***. The subpharyngeal ganglia are located partly in the third and partly in the fourth segments below the pharynx. The two subpharyngeal ganglia are fused together into a single bilobed mass, whence the paired (fused together) ventral nerve cords run backward on the floor of the coelom and below the alimentary canal. In each segment the nerve cord is swollen into a pair of ganglia, which give off three pairs of nerves to the segment.

The epidermis contains many sense organs, each composed of sensory cells. The sensory cell has a hair-like tip ending on the cuticle above. It is connected below to a sensory nerve fibre. The ***photoreceptor cells*** that are sensitive to light occur in large numbers on the prostomium and some of the anterior segments. Each photoreceptor cell includes a "lens" to focus the light and a "retina" of nerve fibrils. The earthworm also possesses tactile, taste and olfactory sensory cells.

Reproductive system.—The earthworm is ***monoecious*** : both male and female organs occur in the same individual. A pair of testes is enclosed in the testes sacs one on either side beneath the alimentary canal in the tenth and eleventh segments. Behind each testes there is a ciliated ***sperm funnel*** connected to a ***vas deferens***. The vasa deferentia are slender tubes extending from the twelfth to the eighteenth segments. Here they join the ducts of the ***prostate glands*** to form a common duct. The prostates are large paired white irregular organs in the sixteenth and twenty-first segments. The testes sacs communicate with the ***seminal vesicles*** behind in the eleventh and twelfth segments.

The female reproductive organs include a pair of ***ovaries*** on the anterior [illegible] thirteenth segment, one on either side of the nerve cord and [illegible] ***oviducts***, with expanded funnel-shaped opening behind the ovary. The cavity of the oviduct is lined by cilia that help moving the ova. The oviducts open to the outside by a common female genital pore ventrally [illegible] fourteenth segment. Four pairs of ***seminal receptacles*** are located in the sixth, seventh, eighth and ninth segments. Each receptacle includes an ***ampulla*** and a duct. The sperms received in copulation are stored in the receptacles until needed for fertilization.

Locomotion.—The earthworm extends the anterior part of its body. The setae are now used in securing a firm hold of the rough surface of the ground. The setae of the hinder part of the body are retracted.

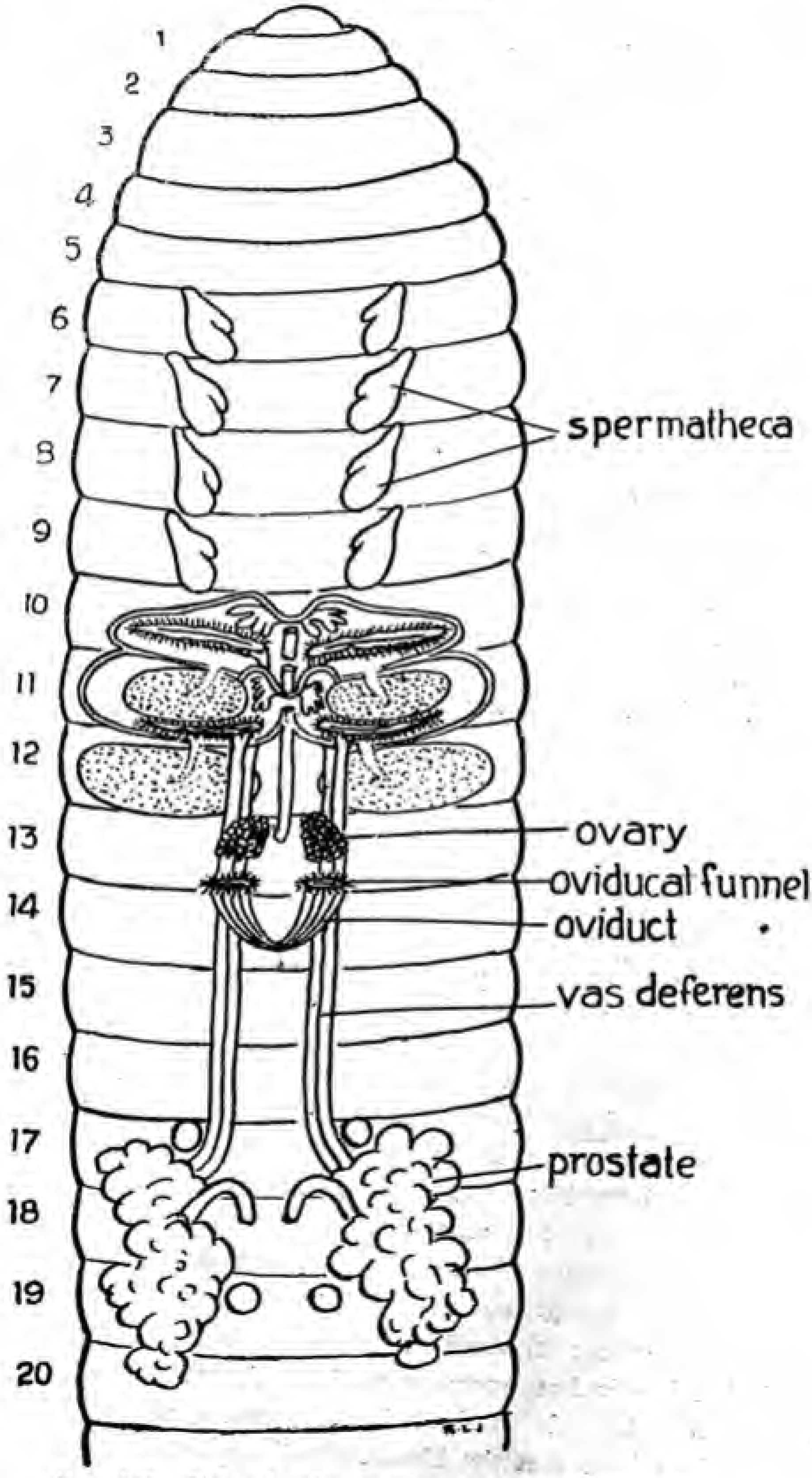


FIG. 186. Reproductive system of *Pheretima posthuma*.

The posterior region of the body is then drawn forward, while the anterior part contracts. The posterior region is then fixed, the anterior region extends forward and the whole process is repeated.

Nutrition and respiration.—The food of the earthworm consists of bits of leaves, small animals, seeds, eggs or larvae of animals and various decaying organic matter that may be found in the soil. The earthworm spends most of its time eating earth underground. All the organic matter present in the soil is digested, while the pure soil is ejected as the familar "worm castings" on the surface. In rainy season, the earthworm comes out on the surface at night and drags small bits of leaves (Fig. 175) down into its burrow to be swallowed in safety. In captivity, it will feed on bits of meat, fat or even dead earthworms. The food that is swallowed is ground up in the muscular gizzard with the help of the sand grains present in it. The stomach and the intestine secrete enzymes like pepsin, trypsin, lipase, cellulase and amylase. Calciferous glands secrete calcium carbonate that neutralises the acidity of any organic matter in order to render the enzymes active.

Regeneration and grafting.—The earthworm has limited powers of regeneration. It can regenerate up to four segments at the anterior end. The head region can be regenerated only if the first ten to fifteen segments have been damaged but not more. The anal segment is regenerated if the posterior segments are lost. Experimentally, earthworms have been grafted together also. The tail ends of two earthworms grafted together for example give rise to a worm with two tail ends.

Reproduction and development.—The earthworm reproduces mostly during the warm rainy season. They mate at night. Two earthworms from adjacent burrows stretch the anterior ends of their bodies out of their burrows. They appose their ventral surfaces, heads pointing in opposite directions in such a way that the clitellum of each worm is opposite the spermathecal pores of the other. After mating, the worms separate. The eggs are laid in a cocoon secreted by the cells of the clitellum. The cocoon slides forward and receives a number of eggs from female genital pore. With these eggs the cocoon still slides forward over the ninth, eighth, seventh and sixth segments, where the sperms from the spermatheca are shed on the eggs through the spermathecal pore.

The eggs of the earthworm contain a small quantity of yolk and the cleavage is holoblastic but unequal, so that micromeres and macromeres result. A hollow blastula is formed. The macromeres of the blastula become invaginated, so that the blastocoele disappears and the archenteron

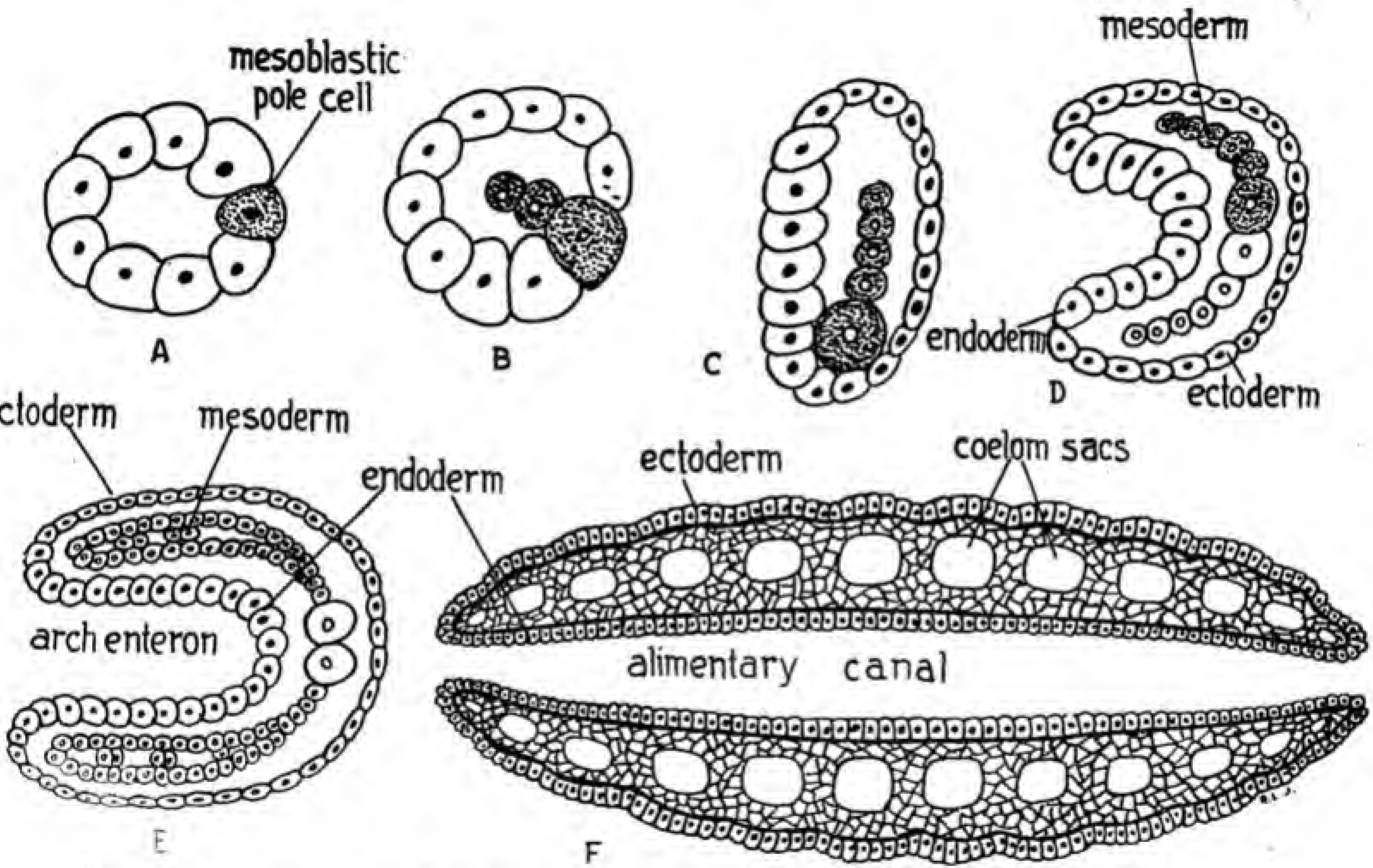


Fig. 1[illegible]7. Development of earthworm (*Lumbricus*). A. Blastula, B. Commencement of mesoderm, C-D. Gastrulation with the formation of archenteron, E. Coelom forming by splitting of mesoderm, F. Later embryo, with metemeric coelom pouches, mouth formed by blastopore and body worm-like. (*Adapted from Storer.*)

appears. Two large ***mesoblastic pole cells*** on the equator of the embryo now divide and form the mesoderm. The mesoderm cells become a number of solid blocks of cells or ***mesoblastic bands.*** Soon the bands split and cavities develop inside. These cavities are the ***coelom*** cavities. The outer mesodermal layer forms the somatopleure and the lower forms the splanchnopleure. New mesoblastic bands or somites form one behind the other. A stomodaeum forms the mouth. The anus is formed very late in the embryo The albuminous material within the yolk is taken into the archentron, where it is digested and absorbed. The young worm hatches in about a month after the eggs have been deposited.

Behaviour.—Being a subterranean animal, the earthworm loves contact, moisture and darkness. It avoids all but the dimmest light and remains concealed within its burrow the whole day long The entrance to the burrow is plugged with bits of leaves or loose soil and at nightfall the lid is pushed aside and the earthworm sallies forth to hunt for food and meet friends. It quickly withdraws into its burrow if a torch is flashed on.

The earthworm is most sensitive to vibrations of the ground : they do not however hear. The vibration set up by the patter of rain drops on the ground is readily felt by them even when they are in their burrows. The earthworm responds to pungent odours.

It has been recently shown that earthworms possess memory and can learn by experience. If the worms are forced into the end of a Y-shaped tube whence they could escape either by the right or left arm, and at one of which they receive an electric shock, they learn to avoid that arm after about three hundred trials.

The earthworm is also said to have its own "taste" for particular kinds of food. For example, it prefers leaves of celery to cabbage and carrot to celery.

Adaptations for a subterranean life.—The earthworm is adapted for a subterranean mode of life. An animal that lives underground, must have its body streamlined to be able to move about among the soil particles. It has no projecting appendages that may interfere with burrowing underground. The setae are used to anchor the body firmly in the burrow. Living in complete darkness underground, the earthworm has no eyes. The photoreceptor cells are most concentrated in the anterior region of the body, which alone is likely to be exposed to light. For a fossorial animal, the sense of touch is most important. The habit of swallowing the soil is one of the adaptations for subterranean life.

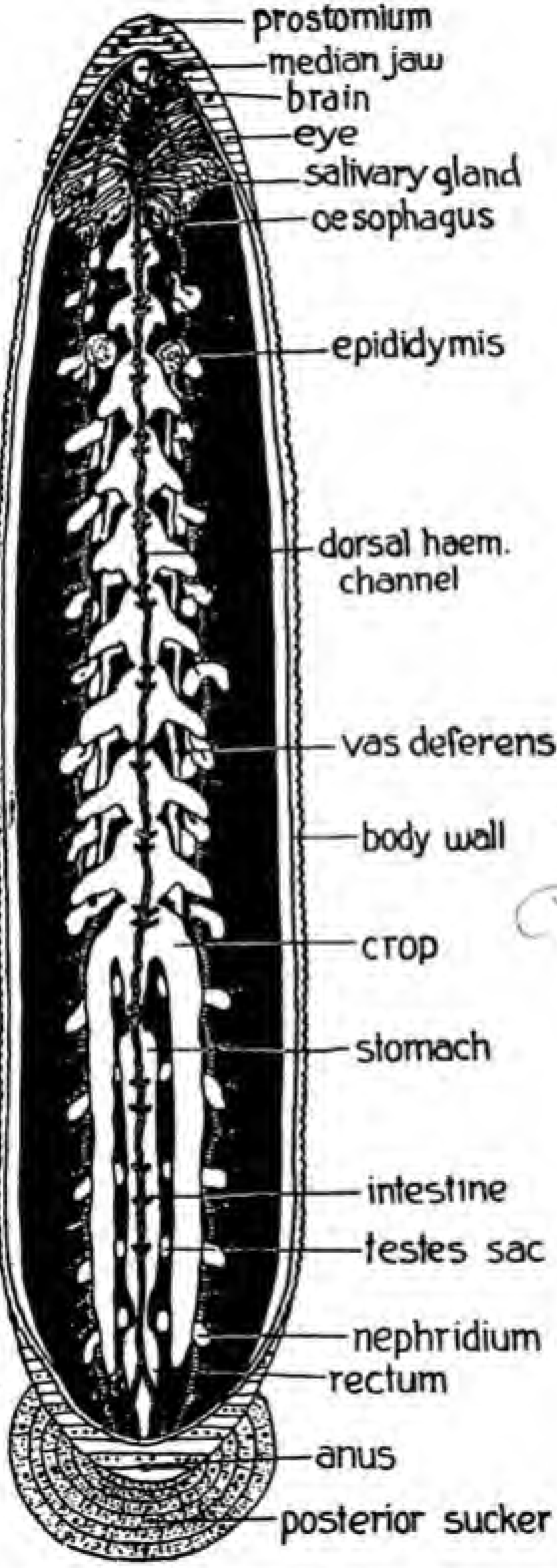


FIG. 188. Leech dissected to expose the alimentary canal, the gonads and the chief haemocoels.

which is in the X segment. The clitellum, a temporary structure developed only during the breeding season, extends over segments IX, X and XI.

The body wall includes 1. a cuticle, 2. an epidermis with slime glands, sensory cells, etc., 3. circular muscles, 4. oblique muscles and 5. longitudinal muscles. The alimentary canal includes 1. a pre-oral chamber formed by the oral sucker, 2. a triradiate mouth with three jaws, 3. a buccal cavity into which the salivary glands open, 4. short narrow oesophagus, followed by 5. a large crop that extends from IX to XVIII segments. The crop is composed of ten metameric chambers one behind the other, each having lateral caeca. The crop opens behind into a short stomach in the XIX segment. The stomach continues behind as the intestine, which opens into the rectum.

The coelom is largely filled up by parenchyma and ***botryoidal*** tissue and is reduced to the so-called ***haemocoelomic*** system of channels. The haemocoelomic channels constitute the circulatory system of the leech. There are four longitudinal channels, one dorsal, one ventral and two lateral, with their branches. The coelmic fluid that contains haemoglobin and leucocytes, circulates through these channels.

The dorsal haemocoelomic channel lies dorsal of the alimentary canal and runs zig-zag the whole length of body. In each segment the dorsal channel gives off two pairs of dorso-lateral and dorso-intestinal branches. It bifurcates in the XXI segment ; the forks pass down into the enlarged hind end of the ventral channel. The direction of flow in the dorsal channel is from behind forward. The ventral channel lies below the alimentary canal and also extends the whole length of the body. It encloses the nerve cord, brain and subpharyngeal ganglia. Two pairs of branches arise from it in each segment. The lateral channels run one on either side of the alimentary canal. They have muscular walls and have valves inside. They thus resemble blood vessels. In each segment they receive two branches and give off one branch. The lateral channels show peristaltic contractions from behind forward. Posteriorly the lateral channels open into the enlargement of the ventral channel. Anteriorly they break up into capillaries.

The general surface of the body constitutes the respiratory organ.

The excretory system comprises seventeen metameric pairs of nephridia in segments VI to XXII. The nephridia open to the exterior by the nephridiopores.

The nervous system resembles that of the earthworm and consists of paired cerebral ganglia, circumpharyngeal connectives, subpharyngeal

ia and segmental ganglia connected by the ventral nerve cord. sense organs include the semicircular eyes on the dorsal surface ie oral sucker and the segmental receptors on minute papillae on segment.

The leech is monoecious. Eleven pairs of testes sacs are found segments XII to XXII. The vas efferens from each sac runs to the deferens. The latter is a pair of slender longitudinal ducts extend- forward to the XI segment. In this segment they enlarge into a nvoluted seminal vesicle. An ejaculatory duct from each vesicle joins atrium in IX and X segments. The atrium includes a penis. A ir of ovisacs in the XI segment encloses the ovaries. The oviducts nite within the ***albumin glands*** to from a vagina.

Locomotion.—Leeches swim under the water by snake-like undulating novements of the body. On a solid substratum they move by arching nd looping the body, using the suckers for attachment.

Nutrition.—The leech pierces the skin of its victim by its serrated jaws. The cup-shaped pre-oral cavity of the anterior sucker, the buccal cavity and the pharynx are used in sucking up the blood that is prevented from coagulating by ***hirudin*** present in the saliva of leech.

Relation to man.—Leeches constitute the food of certain fishes, ducks, snipes and other birds, which in turn form food of man. Leeches often destroy insect larvae, worms, other leeches, molluscs, etc. and might affect man indirectly. They are the worst enemies of buffaloes, cattle, horse and man in paddy fields and in drinking ponds. They also act as vectors for pathogenic organisms. The common Indian paddy field leech *Hirudinaria manillensis* is believed to play the role of vector of the rinderpest disease. In the days past leeches were extensively used in surgery for blood-letting, under the mistaken belief that many diseases may be cured by removing "bad blood". They are thus employed even to this day by ayurvedic physicians. Hirudin extracted from the leeches was used a few years ago as haemolytic agent in allopathic hospitals.

ARCHIANNELIDA

3. POLYGORDIUS

Bionomics and structure.—*Polygordius* is a marine worm that is common in the sand at moderate depths in the Mediterranean sea. Its body is thread-like and measures 3—4 cm. long. The segmentation of the body is indistinct externally. The ***prostomium*** at the anterior end bears a pair of ***tentacles***. The ***mouth*** opens in the first segment directly behind the prostomium. The ***anus*** opens in an oval depression at

the posterior end. Pits lined by cilia on each side of the prostomium function as sense organs. Parapodia or chaetae are absent.

The internal organization is simpler than in the earthworm. The alimentary canal is a straight tube that extends from the mouth to the anus. The coelom is metamerically divided by ***septa***. The internal metamerism corresponds to the external segmentation. Unlike in the earthworm, the coelom is divided in each segment into a right and a left half by partitions, viz. the ***dorsal*** and ***ventral mesenteries***. Except the first and the last, each segment contains a complete set of all the organs: alimentary canal, ventral nerve cord, somatic longitudinal muscles, paired nephridia and gonads. The nervous system consists of a ***ventral nerve cord*** connected by connectives to a ***median ganglion*** dorsally in the prostomium. The body segmentation is thus ***homonomous***. The sexes are separate. The gonads do not have any ducts. The sperms and ova escape by rupture of the body wall. Fertilization takes place in water. A free-swimming ***trochosphere*** (Trochophore) larva (Fig. 189) develops from the egg.

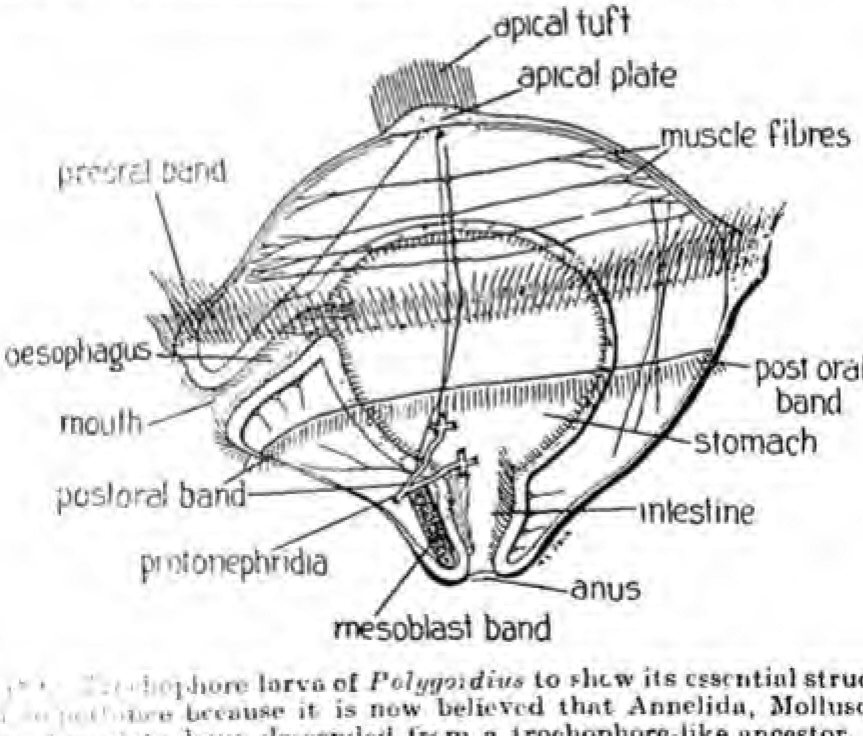


Fig. 189. Trochophore larva of *Polygordius* to show its essential structure. This larva is of importance because it is now believed that Annelida, Mollusca, Echinodermata and Chordata have descended from a trochophore-like ancestor. (*Redrawn from Richard Hertwig, Lehrbuch der Zoologie, Jena, Gustav Fischer : after Hatscheck*).

The trochosphere is shaped like a spinning-top and has a double ***band of cilia*** round its equator. The mouth opens between these ciliated bands on one side. A short oesophagus leads into a large stomach that is followed by a short intestine ending in the anus on the lower pole. The space between the body wall and the gut, containing a few ***stellate***

cells and ***muscular fibres,*** is the persistant blastocoele. On the upper pole a thickened ***apical plate*** functions as the larval sense organ and later develops into the prostomial ganglion of the adult. A pair of delicate tubes with ***flame cells*** constitute the ***protonephridia*** on the side of the stomach. Posteriorly on each side of the intestine is the ***mesoblast*** cell. The lower pole begins to elongate and the mesoblast cells extend back into this elongation. Soon this elongated part becomes segmented and the larva gradually grows into the adult. *Polygordius* is not primitive but a *simplified* worm.

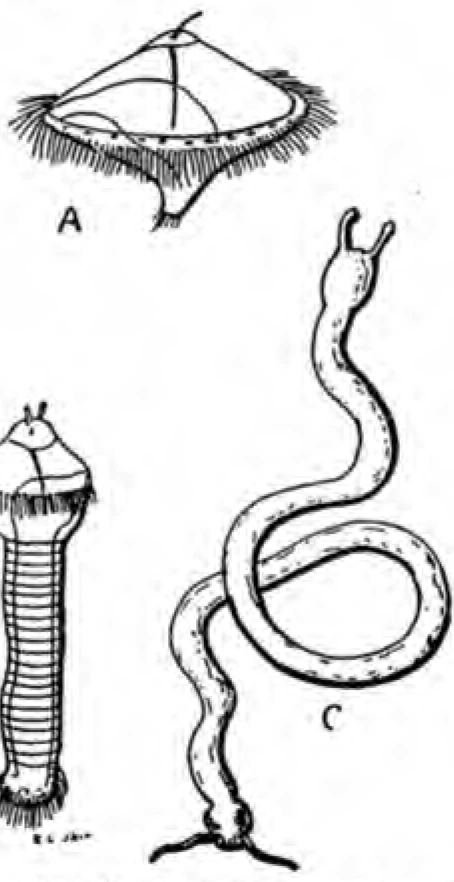


FIG. 190. *Polygordius*, a simplified marine worm, long believed to be a primitive type and hence placed in Archiannelida. A. Trochophore larva. B. Young worm developing from the trochophore. C. Adult worm. *(A & B adopted from Hatschek).*

COMPARISON BETWEEN POLYGORDIUS AND EARTHWORM

POLYGORDIUS	EARTHWORM
1. Marine	Terrestrial or aquatic
2. External segmentation indistinct	External segmentation distinct
3. No chaetae	Chaetae present
4. Tentacles present	No tentacles

5. Cerebral ganglion simple in the prostomium	Cerebral ganglion in the third body segment
6. Right and left coeloms separate in each segment	Right and left coeloms fused in each segment
7. Body wall with only longitudinal muscles	Body wall with both longitudinal and circular muscles
8. Gonads in every segment except the first and the last	Gonads not in every segment
9. Gonadal ducts absent	Gonadal ducts present
10. Trochosphere larva	No trochosphere larva

POLYCHAETA

4. NEREIS

Nereis occurs on the sea coast near the lowtide mark. It spends the daytime hiding under stones or in burrows in sand, with only the head projecting above the surface. It crawls out and swims in search of food at night.

The body of *Nereis* is slender, elongate and greenish. It is composed of numerous ***somites*** or segments as in the earthworm. A distinct ***head*** includes the ***prostomium*** and ***peristomium***. Two short ***prostomial tentacles*** and paired short ***palpi*** laterally on the head distinguish the nereis from the earthworm. There are also two pairs of ***eyes*** on the head. The peristomium also bears four pairs of ***peristomial tentacles***. The tentacles serve as tactile and olfactory sense organs. The last segment of the body bears the anus and the paired ***anal cirri***.

Each segment of the body bears laterally a flat ***parapodium***. The parapodium is the organ of locomotion and is effectively used both in creeping on sand and in swimming. It consists of a dorsal lobe, the ***notopodium***, and a ventral lobe, the ***neuropodium***. The dorsal and ventral lobes each bear a ***cirrus*** and a bundle of ***setae***. The two needle-like chitinous ***aciculi*** of the parapodia serve as supports for the latter and also help in locomotion.

The body wall comprises a cuticle, an epidermis and circular and longitudinal muscles. The parapodia are moved by muscles arising in each segment. The coelomic cavity is divided by ***intersegmental septa*** as in the earthworm. The cavity of each segment is also subdivided into a right and a left half by median dorsal and ventral ***mesenteries***.

The alimentary canal is a straight tube and includes an evertible pharynx with paired horny jaws, a short oesophagus into which open

a pair of digestive glands, and the stomach-intestine extending to the anus. The circulatory system includes a ***dorsal longitudinal*** vessel that exhibits peristaltic contractions and a ***ventral longitudinal vessel*** with transverse branches in each segment. The plasma contains haemoglobin in solution and colourless corpuscles. The integument and the parapodia serve as the respiratory organs. Paired ***nephridia*** are the organs of excretion. The nervous system includes a pair of ***cerebral ganglia*** and median ***ventral nerve cord*** with paired ***ganglia*** and nerves in each segment.

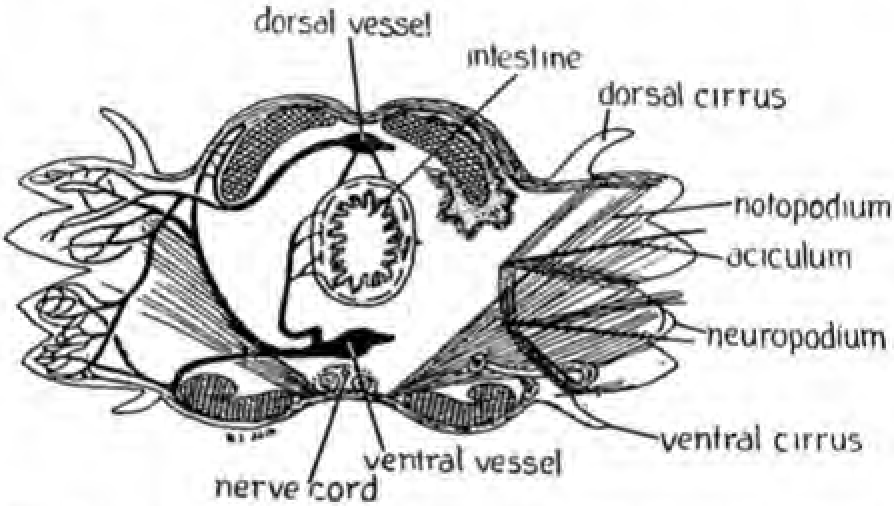


FIG. 191. *Nereis.* Diagrammatic transverse section of a typical segment. Blood vessels are shown on the right. (*Redrawn from Richard Hertwig, Lehrbuch der Zoologie, Jena, Gustav Fischer*).

The sexes are separate, but the gonads are not permanent. Ova and sperms appear only during the breeding season. They are passed out through the nephridia and fertilization takes place in the sea water. A ***trochophore*** larva that develops from the zygote gradually transforms into the adult.

RESUMÉ

I. Annelida

1. The Annelida are segmented worms, that differ from the Nematodes in the metamery of the body and in the possession of a distinct coelom and of appendages.

2. They are subdivided into Archiannelida, Polychaeta, Oligochaeta, Hirudinea and Gephyrea.

II. The Earthworm

3. The earthworms are mostly subterranean Oligochaetes that inhabit a variety of soils.

4. The common earthworms of India belong to the genera *Pheretima* and *Megascolex*,

5. A mass of glandular cells constitute the clitellum around segments 14, 15 and 16.

6. The alimentary canal comprises a conspicucus pharynx, oesophagus, a powerful masticatory gizzard and a straight intestine.

7. The earthworm has a closed circulatory system with red blood that lacks the erythrocytes.

8. In the dorsal vessel the blood runs from behind forward and in the ventral vessel from the front backward. Lateral hearts connect them in the 7, 9, 12, and 13 segments.

8. The excretory system comprises the nephridia, which are coiled tubes with a funnel-shaped opening into the coelom.

9 The nervous system comprises paired supra-pharyngeal ganglia, connected by circumpharyngeal commissures to the subpharyngeal ganglia, that give off the ventral nerve cord behind.

10. The earthworm is monoecious. The testes lie in the 10 and 11 segments and the ovaries in the 13 segment.

11. The earthworm feeds on bits of leaves, small animals, seeds and other organic particles occurring in the soil.

III. **Leech**

12. Leeches live in fresh-water and suck the blood of various animals.

13. Their body consists of 34 segments that are superficially annulated. Anterior and posterior suckers help in locomotion and in sticking to their prey.

14. The alimentary canal includes a large crop behind the oesophagus. The crop is composed of a series of chambers with lateral caeca.

15. Leeches were formerly employed in phlebotomy.

CHAPTER XII

MOLLUSCA

Mollusca. The MOLLUSCA are soft-bodied unsegmented animals, typically with an anterior head, a ventral foot and a dorsal visceral mass. The body is surrounded by a more or less fleshy mantle and is commonly sheltered in a calcareous shell. They include chitons, tooth shells, clams, oysters, snails, slugs, cowries, squids, nautili, octopuses, etc. After the Arthropoda, the Mollusca are the most abundant animals. They are mostly marine but some inhabit fresh-waters and a few are terrestrial. Several of them are of great economic importance.

Characters.

1. Triploblastic, unsegmented, bilaterally symmetrical (the viscera coiled in some) or asymmetrical.
2. Epithelium single-layered, mostly ciliated and with mucous glands.
3. Body enclosed in a thin dorsal mantle that secretes a calcareous shell of one, two or eight pieces. Shell internal or reduced in some.
4. Except in some, the head distinct.
5. Ventral muscular foot for creeping, burrowing or swimming.
6. Alimentary canal complete, often U-shaped; mouth with radula bearing transverse rows of chitinous teeth.
7. Heart dorsal, with one or two auricles and one ventricle, in pericardial cavity.

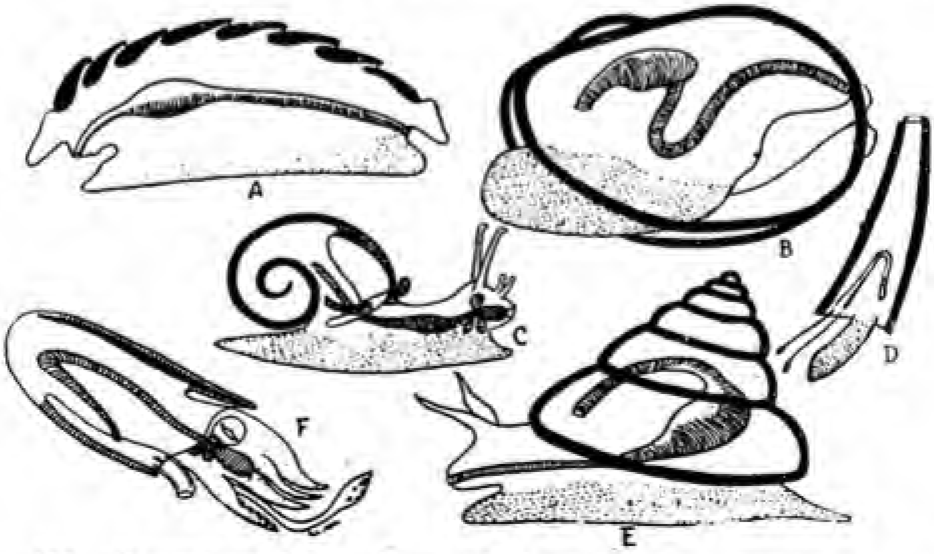


FIG. 192. Diagram of the molluscan body plan—shell, mantle, foot—and its modifications in A. Amphineura, B. Pelecypoda, C. & E. Gastropoda, D. Scaphopoda, F. Cephalopoda. Shell black, foot dotted, gut striped.

8. Respiration by gills, lungs, mantle or epidermis.

9. Excretion by kidneys.

10. Three pairs of nerve ganglia joined by longitudinal cords and cross connectives and nerves.

11. Sexes generally separate.

Fig. [illegible]. Some common shells of tropical seas. A. *Pterocera*. B. *Tapes*. C. *Oliva*. [illegible] F. [illegible] *Mitra*. G. *Neritas*. H. *Cypraea*. I. *Strombus*. J. [illegible] M. *Mytilus*. N. *Solarium*. O. *Bulla*. P. *Dentalium*. Q. *Melongena* (=*Pyrula*). [illegible] shells is an interesting, instructive and often paying hobby for those [illegible] sea shore. Some of the shells are objects of great beauty. (*Original photograph of specimens in the Zoology Museum, St. John's College, Agra.*)

Molluscan shape of body.— The Mollusca have diverse forms: The Amphineura have flat foot with the body partly covered above by eight overlapping calcareous plates (Fig [illegible]). The Scaphopods are enclosed in an elongate tubular shell open at both ends. The Pelecypods are laterally compressed, lack a head and are enclosed within a pair of hinged shells. The Gastropods have distinct foot and head, and the viscera is usually enclosed in a spiral shell, coiled either to the right or to the left. In the

Cephalopods the large head bears conspicuous eyes and numerous fleshy arms. The shell is usually internal or absent.

The Mollusca resemble the marine Annelids in the type of cleavage of the zygote and in the trochophore larva. They differ from the Annelida in the absence of body segmentation, reduction of coelom and of the ganglia.

FIG. 194. Some notable molluscan shells. A Pearly *Nautilus*, with the [illegible] chambers exposed in C *Strombus gigas*. D. *Haliotis* the ear-shell is a Gastro[illegible] which the spire of the shell is very much reduced and the last whorl is ve[illegible] E. & F. *Vestiarum*. G. *Trochus niloticus* the top-shell, which was fished by the [illegible] in large numbers before World War II from the Andaman Coast for manufa[illegible] ornaments, hair pins, snuff boxes and the like. (*Original photograph of* [illegible] *the Zoology Museum, St. John's College, Agra*).

Classification.—The Mollusca are classified as below :

Phylum MOLLUSCA. Unsegmented, bilaterally symmetrical or [illegible], covered by mantle that secretes the shell, ventral muscular [illegible] visceral mass.

Class 1. AMPHINEURA. Body elongate. Shell of eight pl[illegible] absent. Nerve ring and two pairs of nerve cords. No [illegible]. Marine. Example : *Chiton*.

Class 2. SCAPHOPODA. Shell and mantle tubular, open at both ends. Foot conical. No gills. Marine. Example: *Dentalium* tooth or tusk shell.

Class 3. PELECYPODA (=Lamellibranchiata). Shell of two lateral valves, hinged together dorsally. Margins of the mantle form the siphons. No head, jaws or radula. Foot often hatchet-shaped. Gills usually plate-like. Examples: *Unio* fresh-water mussel, *Teredo* shipworm, *Ostrea* oyster.

Class 4. GASTROPODA. Visceral mass in a spirally coiled shell. Head distinct, with one or two pairs of tentacles. Foot large, flat. Examples: *Haliotis*, *Strombus* giant conch shell, *Cypraea* cowries, *Helix*, *Pila* snails.

Class 5. CEPHALOPODA. Shell external, internal or none. Head large with complex eyes, horny jaws and radula, 8 or 10 arms. Brain in a cartilage-like covering. Examples: *Nautilus*, *Loligo* squid, *Sepia* cuttlefish, *Octopus*.

Relation to man.—The Mollusca are of great economic importance. From time immemorial man has used scallops, clams, mussels, oysters, snails and other "shellfish" as food. The shells of Mollusca have served as ornaments and as money. "Pearl" buttons are manufactured (Fig. 195)

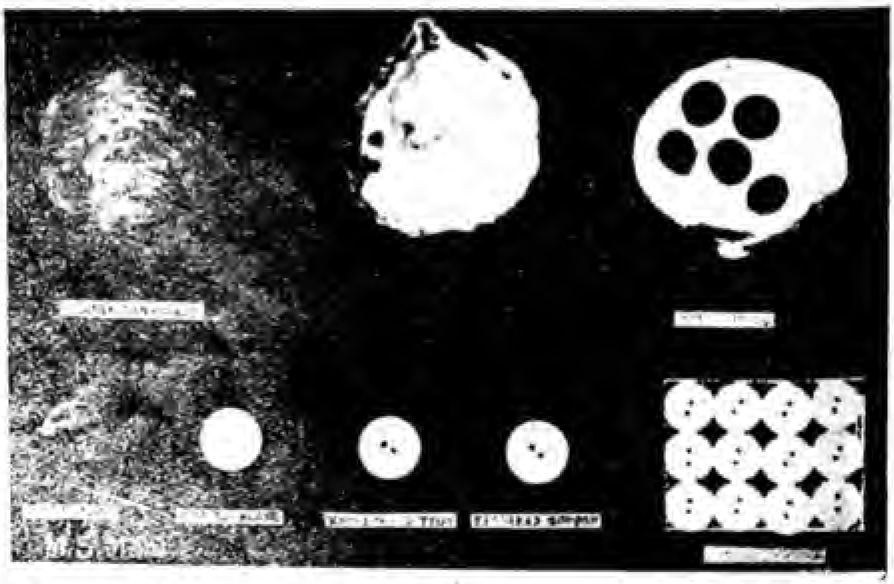


Fig. 195. "The 'pearl' buttons" are manufactured from the shells of fresh-water clams. Circular blanks, cut from the shells, are polished and bored with holes for the thread. Rings, bangles, carved images of gods and goddesses and other works of art are made from various marine shells in South India. *Original photograph of a show case in the Zoology Museum, St. John's College, Agra*).

from the shells of marine and fresh-water clams (*Unio*). Pearls are obtained from Molluscs. The mantle secretes thin layers of nacre around some foreign irritating substance like sand grain, larvae of nematodes or trematodes. The iridescence of the pearl is due to the refraction of light from the concentric layers of calcium carbonate near the surface. The oldest pearl fisheries of the world are in South India and Ceylon. Pearls are also cultured in Japan. The large conch shells are converted into

musical instruments. Some shells are also used in medicine. Sepia is a well known pigment that is obtained from the ink of the cephalopod *Sepia.* The thin flat shells of *Placuna placenta* are cut into squares and used as decorative window glass.

Some of the Mollusca are harmful to man. The oyster-drill snail attacks oysters and mussels by boring circular holes in their shells. It then rasps off the soft parts of its victim by means of the radula. *Teredo navalis*, the dreaded shipworm, burrows into the wood of ships and wooden piling of harbours by means of the sharp edges of the separate short valves of its shell. In San Francisco Bay alone the shipworm is reported to have caused damage to wooden structures estimated at $ 25,000,000 during 1917—1921.

Some of the large squids and octopuses are greatly feared by fishermen and divers.

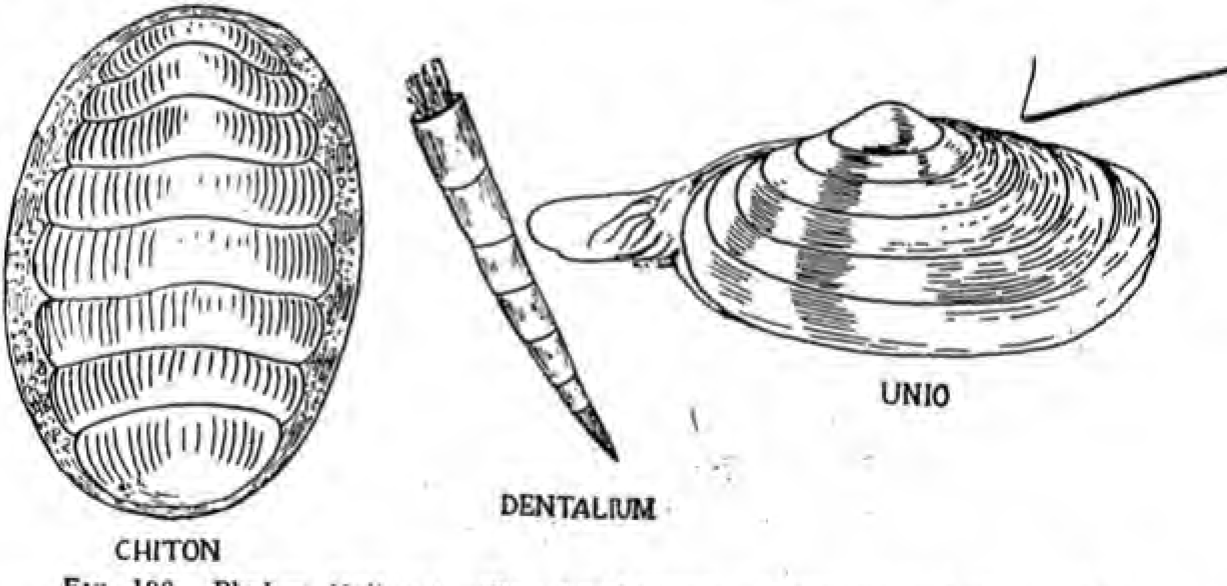


FIG. 196. Phylum Mollusca. Class Amphineura : *Chiton* or coat-of-mail-shell occurs on submarine stones and can roll itself tightly into a ball if threatened. Class Scaphopoda : *Dentalium*, the elephant tusk shell, open at both ends, is a burrowing mollusc that spends most of its time half buried in the sand of the sea bottom. Class Pelecypoda : *Unio* a fresh-water clam or mussel, the shell of which is used in manufacture of pearl buttons.

AMPHINEURA

The members of this class have elongate elliptical ***body*** with a convex dorsal surface covered by eight overlapping ***plates*** (Figs. 192, 196). The plates are covered by a fleshy ***girdle*** that is part of the ***mantle.*** The ventral surface is largely occupied by the fleshy ***foot***. The mouth is at the anterior end. On the floor of the buccal cavity is a long ***radula*** with transverse rows of chitinous teeth. The alimentary canal consists of a

short pharynx, a stomach and a coiled intestine that ends at the anus posteriorly. Numerous pairs of ***gills*** occur in the ***pallial groove*** between the mantle and the foot. The nervous system comprises a ***nerve ring*** round the mouth, that gives off two pairs of ventral longitudinal nerve cords, connected together by cross nerves. The sexes are separate.

The class Amphineura is divided into two orders :

Order 1. APLACOPHORA. (=Solenogastres). Wormlike. With numerous calcareous spicules in the thick integument but no shell. Foot rudimentary. Bottom dwellers. Examples: *Chaetoderma*, *Neomenia* from the North Atlantic.

Order 2. POLYPLACOPHORA. (=Loricata). Body elliptical. Shell dorsal row of eight plates. Foot large. Gills 6-80 pairs in grooves. Larva trochophore. On rocks in coastal waters. Examples: *Chiton*, *Cryptochiton*, *Chaetopleura*.

SCAPHOPODA

The SCAPHOPODA have their body elongate dorsoventrally. It is surrounded by a fleshy mantle that secretes a tubular shell open at both ends and tapers slightly at one end. The pointed foot protrudes through the broader end of the shell and helps in burrowing. There is no head. The mantle functions as the respiratory organ. The shells of *Dentalium*, tusk shell, were used as money by the American Red Indians.

PELECYPODA

The PELECYPODS are bilaterally symmetrical, compressed, acephalic molluscs, enclosed in a bivalved shell. They are all aquatic, mostly marine and bottom dwellers. The class is divided into the following orders :

Order 1. PRIONODESMACEA. Margins of the mantle generally separate below and behind, with imperfect siphon. Examples: *Nucula*, *Arca*, *Ostrea* the oysters, *Mytilus* the sea mussel, *Pecten* the scallop, *Unio* and *Anodonta* fresh-water mussel.

Order 2. TELEODESMACEA. Margins of the mantle more or less connected below and behind, siphons usually well developed. Examples: *Cardium*, *Venus*, *Mya*, *Pholas* that burrows in clay and rock, *Teredo* the shipworm.

Order 3. ANOMALODESMACEA. Margins of the mantle united below and behind, with holes for the foot and siphons. No gills. Example: *Cuspidaria*.

1. UNIO*

UNIO, the fresh-water mussel is a bilaterally symmetrical soft-bodied animal that is enclosed in a bivalved shell. It lives partially imbedded in sand or mud at the bottom of fresh-water streams. It moves but little and often remains in exactly the same place for long periods of time. Its

* The Unio that is commonly dissected in India is *Lamellidens* (*Lamellidens*) *marginalis* (Lamarck).

food consists chiefly of organic particles, microscopic animals and plants brought in through a current of water by ciliary activity. The mussel can keep its shell closed so tightly that it is impossible to force it open without breaking. When the animal dies, the muscles relax and the shell gapes open. When undisturbed, the animal lies partly buried in mud or sand, with the shells slightly agape. Its heavy shell is so cumbersome to carry about that it can hardly run down its prey. Instead it draws the water through its body and strains off minute particles of food. For protection it relies wholly on its heavy shell into which it retires.

Systematic position.—

Phylum MOLLUSCA
  Class *PELECYPODA*
    Order PRIONODESMACEA
      Superfamily *Naiadacea*
        Family Unionidae
          Genus *Unio* or
            Genus *Lamellidens*.

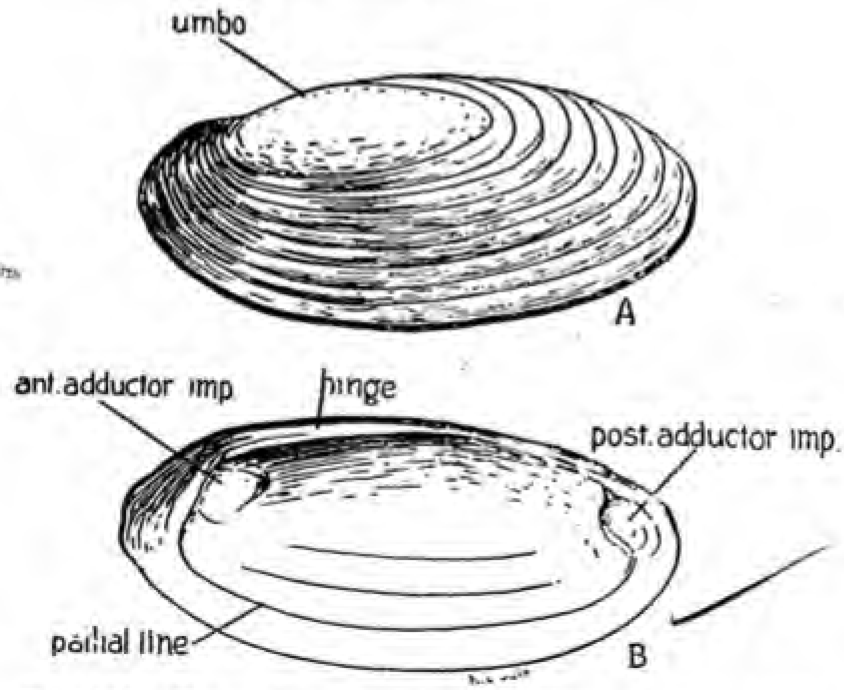


FIG. 197. *Unio.* Shell. A. From outside. B. From inside.

The shell.—The soft-bodied animal is enclosed in a calcareous shell. The shell consists of two lateral ***valves*** that are hinged together dorsally. When viewed from the side, the shell is oval, somewhat rounded anteriorly, angulated behind, thickest above and just behind the middle,

The two valves are fastened dorsally by an elastic ***hinge ligament***, that draws them together dorsally and thus makes them gape below. Close to this ligament is the ***umbo*** nearer to the anterior than to the posterior end. This represents the oldest point of the shell. Around it are the concentric ***lines of growth***. On the inner surface of the valve, ***hinge teeth*** are present on the dorsal side. Roughened impressions indicate the places of attachment of the powerful ***adductor muscles***, that keep the shell closed. The ***pallial line***, a little away from and parallel to the ventral margin, marks the attachment of the muscular layer of the ***mantle***. The shell comprises 1. an outer ***periostracum*** of a horny material called ***conchiolin***, 2. a ***prismatic layer*** of conchiolin impregnated with calcium carbonate and 3. an inner ***nacreous*** or mother-of-pearl layer, also of lime in thin lamellae.

Soft parts.—The shell encloses the bilaterally symmetrical, compressed soft body, comprising a ***visceral mass***, produced dorsally on each side into a muscular fold, the ***mantle*** or ***pallium*** and ventrally into a keel-shaped, extensile muscular ***foot***. There is no head. The visceral mass fills the upper part of the space between the two valves. It contains the organs of digestion, circulation, excretion and reproduction. The mantle is an important organ characteristic of mollusca. It is really a fold of the dorsal wall of visceral mass of the animal. It encloses a large ***mantle cavity*** or ***subpallial space***. The free margin of the mantle is thickened into a prominent groove. The edges of the flaps are free except posteriorly where they are fused together enclosing a pair of slit-like passages in between. The ventral passage is the ***inhalent siphon*** that opens to the outside by the ***inhalent aperture*** bordered by small tentacles. The dorsal passage constitutes the ***exhalent siphon***. In a living animal a current of water enters through the inhalent aperture and leaves by the exhalent aperture. The epithelium of the thickened edge of the mantle secretes the outer and middle layers of the shell.

The mouth is unarmed and opens in the middle line below the anterior adductor muscle. It is bounded on each side by two triangular flaps the ***internal*** and ***external labial palps***. The short oesophagus leads to a large stomach, the intestine descends into a visceral mass, coils on itself, ascends, proceeds as rectum through the pericardium and finally opens by anus into the exhalent siphon above the posterior adductor muscle. There is a typhlosole. The stomach and the coiled part of the intestine are imbedded in a mass of ***digestive glands***.

On each side of the visceral mass and above the foot is a single ***ctenidium*** or gill. It is composed of an outer and an inner ***lamina*** or gill plate. Each lamina is formed by an inner and an outer ***lamella,*** united along the anterior, ventral and posterior edges but free dorsally. In a transverse section, the four lamellae of each side resemble a W (Fig. 196). The outer lamella of the outer lamina of each gill is attached the whole of its length to the mantle. The inner lamella of the outer lamina

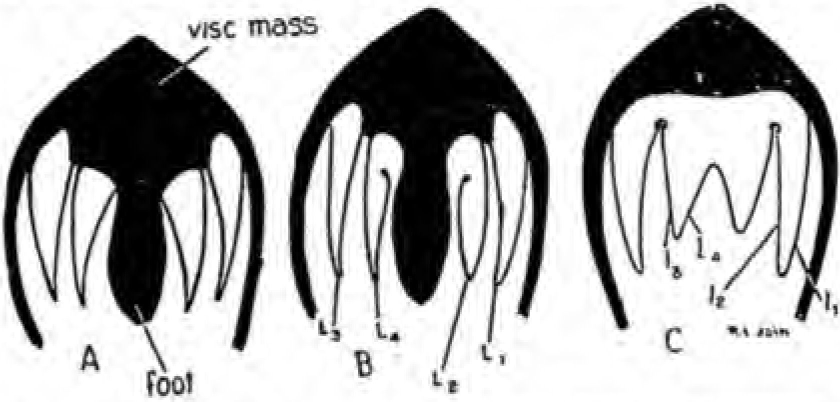


FIG. 198. *Unio.* Respiratory system in vertical transverse sections. A. In the region of the anterior part of foot. B. In the region of the middle of foot. C. In the region behind the foot. Foot, mantle and visceral mass in solid black. L_1, L_3 outer laminae, L_2, L_4 inner laminae, l_1 outer lamella of the outer lamina, l_2 inner lamella of the outer lamina, l_3 outer lamella of the inner lamina and l_4 inner lamella of the inner lamina of the gills.

is attached to the outer lamella of the inner lamina. The inner lamella of the inner lamina is attached anteriorly to the visceral mass, free in the middle but behind the foot it is attached to the corresponding lamella of the gill of the opposite side. There are thus two ***branchial chambers*** anteriorly and posteriorly on each side. These communicate in the middle with the ***suprabranchial chamber*** above. Behind the foot the four branchial chambers open into the suprabranchial chamber that communicates to the outside by the exhalent aperture.

The lamellae are porous and their outer surface is covered by cilia. The action of the cilia sets up a current of water through the inhalent siphon into the mantle cavity and out at the exhalent siphon. The ingoing water carries with it not only the oxygen necessary for respiration but also the minute food particles. The latter are swept off into the mouth by the cilia that cover the labial palpi. The outgoing water carries with it the excretory products and also the effete matter discharged by the rectum.

The blood is colourless and contains colourless corpuscles. The circulatory system comprises a three-chambered ***heart,*** enclosed in a

pericardial cavity. The two auricles lie to the right and left of the ventricle that surrounds the rectum. The oxygenated blood from each gill returns to the auricle of its side by ***efferent branchial veins.*** The auricles empty into the ventricle. From the ventricle arises an ***anterior aorta*** above the rectum and a ***posterior aorta*** below the rectum. The anterior aorta supplies blood to the mantle and to the body. The venous blood from the foot, visceral mass and posterior part of the body collects in a stout ***vena cava*** below the pericardium. The vena cava gives off a number of ***afferent branchial veins*** to the gills. The blood from the mantle returns directly to the auricle and does not go to the gill.

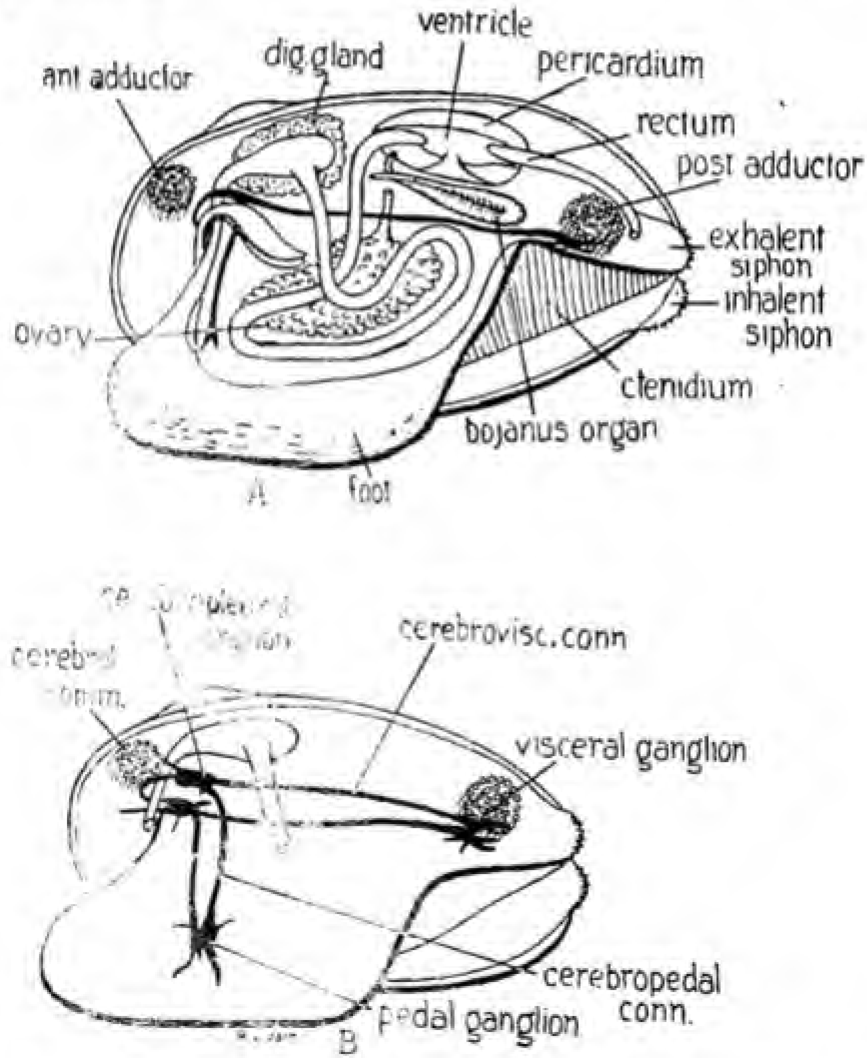


Fig. 199. [illegible] A. Diagram of general internal morphology. B. Nervous system.

The excretory organs, called the ***organs of Bojanus,*** consist of paired structures under the floor of the pericardial chamber. Each is

essentially a tube bent upon itself, opening into the coelom at one end and to the exterior at the other end. Each comprises a spongy glandular ***kidney*** and a thin-walled ***bladder***. The kidney opens in front into the pericardium The bladder opens between the two lamellae of the inner gill lamina.

The nervous system comprises a small ***cerebropleural ganglion*** on either side of the oesophagus, connected together by a transverse ***cerebral commissure*** above the oesophagus. The ***cerebropedal connective*** extends downward and backward to a bilobed ***pedal ganglion*** on each side at the junction of the foot with the visceral mass. The pedal ganglion represents the two fused ganglia of the foot. On each side a long ***cerebrovisceral*** connective passes backward through the Bojanus organ and ends in the two fused ***visceral ganglia*** below the posterior adductor. Each of the ganglia gives off nerves to different parts of the body. One of the important nerves from the cerebropleural ganglia goes to the ***statocyst***, a small vesicle behind the ganglion. It contains a calcareous statolith and serves as a static organ. The visceral ganglia are surrounded by the ***osphradium***, a patch of columnar epithelium of olfactory function.

Development.—The sexes are separate. The unpaired reproductive organs lie in the body mass above the foot. The ***vas deferens*** in male and ***oviduct*** in female open into the suprabranchial chamber. The sperms pass out through the dorsal siphon and reach the female. The ova do not leave the body but are fertilized in the gills, where they reach. The eggs undergo unequal but complete cleavage. Segmentation and invagination lead to a gastrula with small archenteron. Some of the cells of the gastrula are budded off into the blastocoele and form mesoderm. Simultaneously a deep invagination leads to the ***shell gland***. This marks the dorsal surface of the embryo. A tuft of cilia indicates the posterior end. The shell gland becomes a plate of long, cylindrical cells, from which an *unpaired* shell is secreted This is replaced very soon by bivalved shell of triangular shape, the ventral angles of which are produced into spinous incurved hooks. The body now becomes cleft from below upwards and thus gets divided into a single dorsally placed body proper and paired right and left ***mantle lobes***. Upon the latter brush-like sense organs appear and on the ventral surface a glandular pouch secretes a long thread-like ***byssus***. Mesoderm gives rise to one adductor muscle The larva is now called ***glochidium*** and remains within the brood pouch. Later on, the outer gill lamina appears and

produced into a finger-shaped diverticulum. On the ventral wall of this diverticulum is a chitinous band, armed above by numerous minute rasp-like ***teeth*** in transverse rows. The chitinous band is the ***radula*** and the diverticulum is the ***radula sac***. There are seven teeth in each transverse row in *Pila*: two marginal teeth, one lateral on each side of a central ***rachidian***. The radula works against a chitinous bar, the ***jaw*** in the upper part of the buccal cavity. A pair of ***salivary glands***, situated behind on each side of the buccal mass, opens into the oesophagus. The oesophagus, after a short median course, turns to the left and enters the visceral mass. The stomach is a large pouch and encloses a broad U-shaped cavity. The intestine takes several turns in the visceral spire and ends in the rectum. The ducts of the paired digestive glands open into the stomach.

Circulatory system.—The perivisceral cavity is situated on the left side of the body whorl. It is nearly triangular in outline and extends dorsally between the two chambers of the renal organ. The pericardial cavity communicates with the posterior chamber of the kidney by a ***reno-pericardial pore***.

The heart has a single ***auricle*** and one ***ventricle***. The heart, the main aorta and the first part of the arteries lie within the pericardium. The auricle lies dorsad of the ventricle. It is a thin-walled sac capable of distension. Into it open the ***efferent ctenidial sinus***, the ***efferent renal*** and the ***pulmonary veins***. Semilunar valves guard the auriculo-ventricular opening. The ventricle has spongy wall. The main aortic trunk arises from the lower end of the ventricle. The aorta divides into an anterior ***cephalic aorta*** and a posterior ***visceral aorta***. Within the pericardium, the cephalic aorta is enlarged into the ***aortic ampulla*** shortly after its origin. The cephalic aorta gives off arteries to the skin, oesophagus, left side of the mantle and osphradium on the outer side and a small branch to the renal and genital organs on the inner side. The aorta crosses the oesophagus to the right, runs below it and supplies blood to the radula, buccal mass, tentacles, foot, etc. The visceral aorta supplies branches to the digestive glands, stomach, intestine, etc.

The venous blood collects in numerous ***blood lacunae***, that unite together and open into the large ***perivisceral*** and ***peri-intestinal sinuses***. From these sinuses the blood flows into the ***pulmonary sac*** for aeration or into the ***renal sinus*** for purification. Some blood returns to the heart from the renal chamber without aeration by way of the ***efferent renal veins***. The rest of the blood from the renal organ flows into the ctenidium for aeration. The snail is capable of both aquatic and aerial modes of respiration.

facing the observer, the aperture is on the right. The whorls coil downward from the nucleus clockwise, i.e., to the right. Such a shell is described as ***dextral***. The shells of most gastropods are dextral. Occasionally the spiral is reversed and we have a ***sinistral*** shell (Fig. 201).

Soft parts.—The skin of visceral mass is produced into a ***mantle***, that serves as a protective cloak round the anterior part. It encloses the head when the snail retracts within its shell. The thickened edge of the mantle secretes the shell.

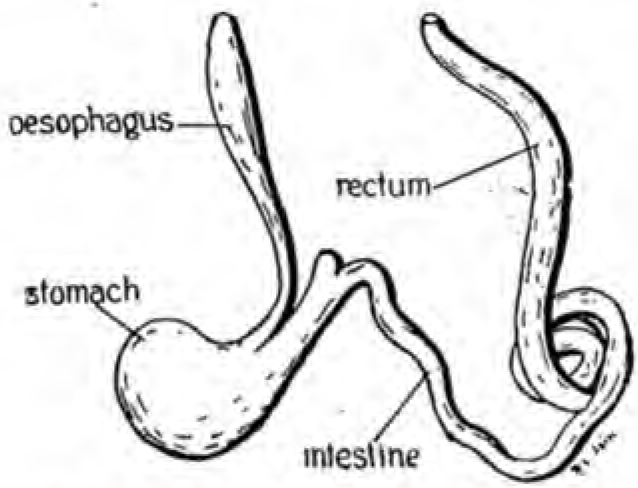


Fig. 202. *Pila globosa.* Alimentary canal.

The head is prolonged into a ***snout***, with a pair of ***labial palpi*** and ***anterior tentacles***. Behind the latter are the longer ***true tentacles***. Small ***stalked eyes*** are located at the base of the true tentacles. Both the pairs of tentacles are contractile and can be withdrawn. The ***mouth*** opens anteriorly in the median line on the ventral surface of the head. A circular opening below the right of the true tentacle is the ***generative aperture***. A large nearly circular aperture on the right side between the mantle and the visceral mass leads into the ***pulmonary chamber***. The anus is a slit-like opening close to the pulmonary aperture.

The mantle encloses dorsally a large ***mantle cavity***, containing the gill, the pulmonary sac, the osphradium, the penis, etc. The floor of the cavity is formed by the body wall.

The alimentary canal.—The mouth leads into a large ***buccal cavity*** contained in a pyriform ***buccal mass***. It is the masticatory part of the alimentary canal. On the floor of the pharynx is the characteristic ***odontophore***, the rasping organ. The posterior part of the floor of the pharynx is

the larvae escape from the parent through exhalent siphon. The glochidia are carried by currents and if they meet a fish, they fix themselves to its gill filaments by the hooked valves. They become the parasites of the fish, in which they get encysted within the mucus or skin of the host and absorb nourishment by the mantle. The ectoparasitic life lasts for ten weeks and during this time metamorphosis takes place. The provisional byssus and sense organs disappear and stomodeum is formed and

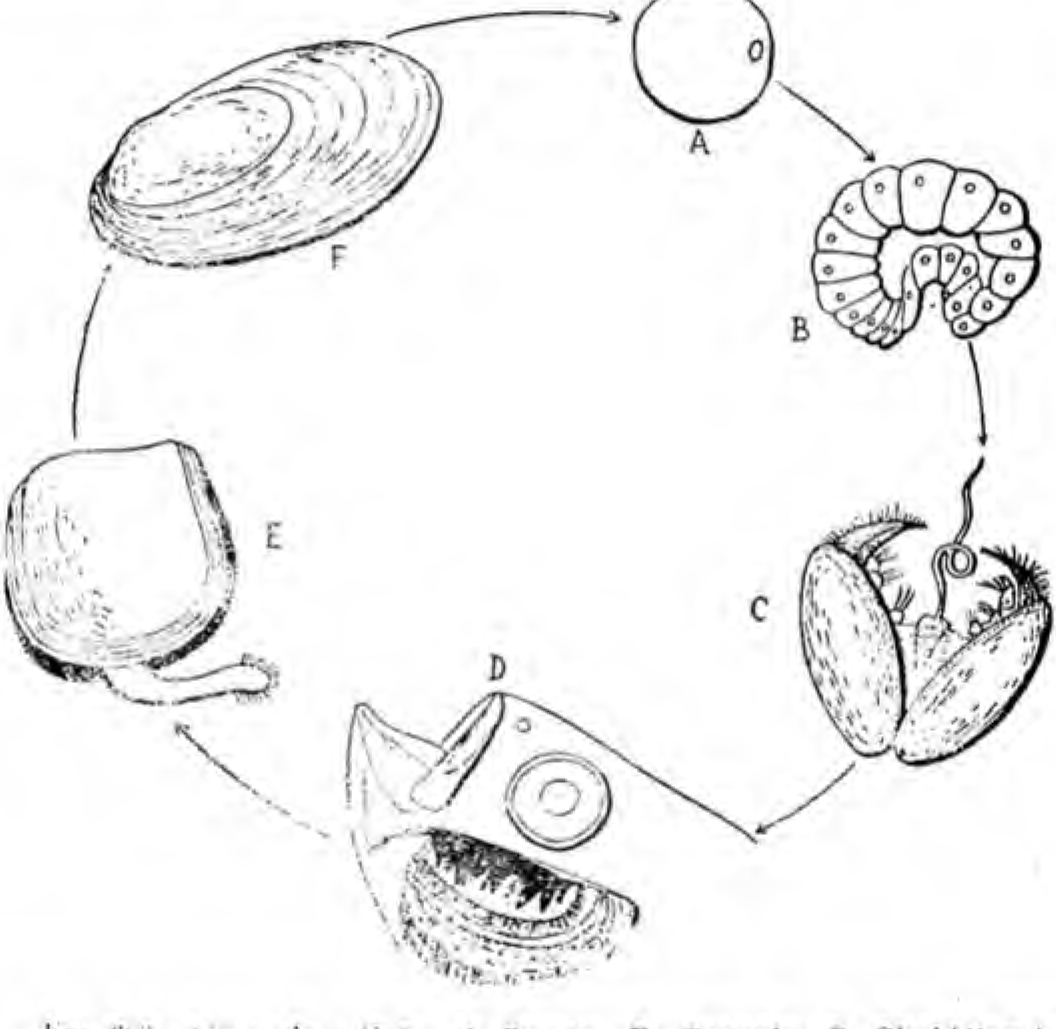


Fig. 290. Life-cycle of *Unio*. A. Zygote. B. Gastrula. C. Glochidium larva with provisional byssus and hooks for attachment. D. Fish gills with the glochidia as parasites. E. Young unio with the foot extended. F. Adult within the closed shell.

communicates with archenteron. Anus appears by rupture of ectoderm covering the posterior end of archenteron. Foot comes as a median ventral elevation behind the mouth. Two papillae and rudiments of gills appear. The young unio drops off from the host and gradually becomes the adult.

CHAPTER XIII

ARTHROPODA—THE PRAWN

Arthropoda.—The ARTHROPODA (*arthros*=jointed, *podos*=foot) far exceed both in number of species and individuals all the rest of the animals, living at the present time. There are nearly five times as many Arthropods as the rest of the Animal Kingdom.

Arthropods live wherever life is possible on the earth : they occur in the oceans at great depths more than five miles, in fresh-water lakes, streams, ponds, hot-springs, sulphur-springs, over high mountain ranges 20,000 feet above the sea level, in the desert, underground, in or on plants and animals. They have even invaded the air. The phylum represents the highest development among the Non-Chordata. The arthropods also constitute economically the most important of all animals.

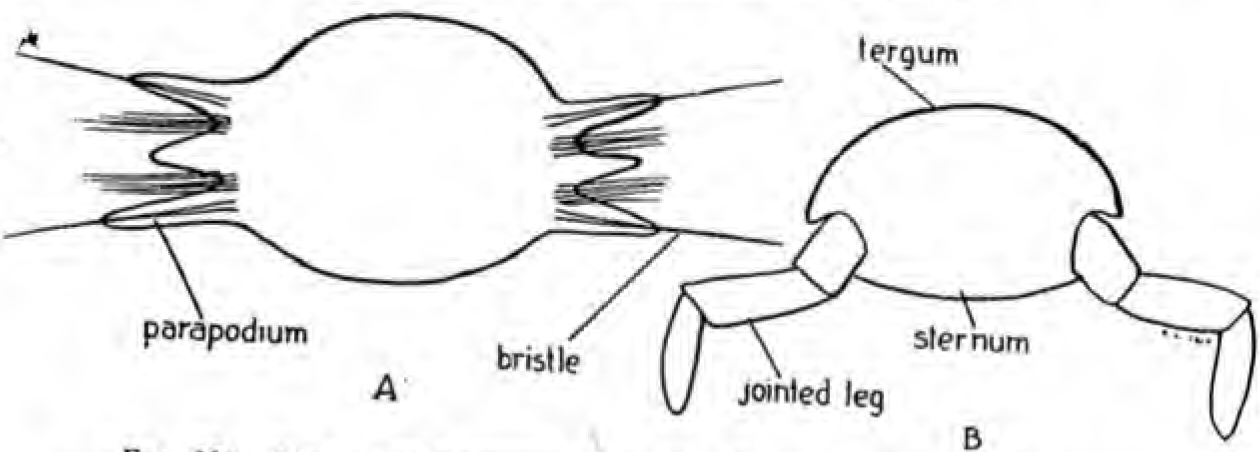


FIG. 208. Diagram of a segment of A. Annelid and B. Arthropod in transverse section to show the fundamental differences : absence in Annelid and presence in Arthropod of jointed appendages as locomotor apparatus.

The arthropodan plan of body (Figs. 208, 210) is roughly an "elaboration and specialization" of the annelidan scheme. Primitively the body consists of a series of similar segments, each with a pair of similar jointed appendages. They also differ from all the other phyla in the possession of segmented appendages. The cuticle, which is thin in the annelids, is thick and rigid in the arthropods. It furnishes a supporting frame-work for the softer parts and also provides attachment for the muscles. It differs from the skeleton of the frog in that it does not lie on the inside and is not surrounded by the muscles, but forms the outer armour enclosing

propulsion of body. The *fins* are used in steering. Above the rectum is the *ink sac*, with its duct opening near the anus. The ink is a dark-coloured pigment that is forced out of the siphon to create a

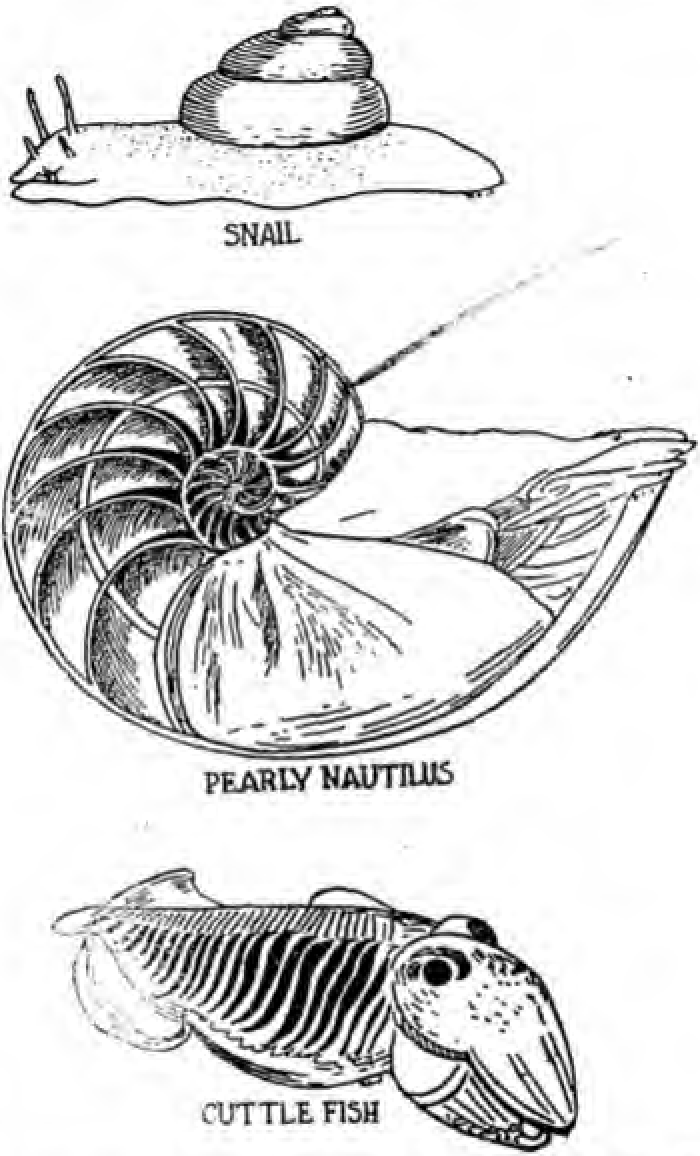


FIG. 206. Phylum Mollusca. Class Gastropoda : snail. Class Cephalopoda : Pearly *Nautilus* occurs around New Caledonia, the Fiji and Philippine Islands. Its shell is distinguished from that of a Gastropod in that it is partitioned by septa. It is the sole survivor of an once flourishing group. Cuttlefish has internal shell. When disturbed, it pours into the water a dark ink from its ink-gland—a simple smoke-screen behind which it escapes from its enemy.

"smoke-screen," under cover of which the squid escapes from its enemy. A *branchial heart* pumps the venous blood to the gills, whence the purified blood collects in an auricle on each side. These open into a single ventricle of the *systemic heart* that pumps the blood to the various parts of the body. The eyes have cornea, lens, aqueous and vitreous

the upper hemisphere of the gastrula. The gut opens to the outside by the ***blastopore,*** that becomes soon narrowed and slit-like. Unequal growth of the lower hemisphere pushes the blastopore to one side, which later becomes the ventral surface of the adult. The embryo is now a trochophore larva very much similar to that of the Annelid. It escapes from the egg membranes and begins to swim by the action of cilia. The mouth opens just below the ciliated band and leads into a blind alimentary canal or the intestine ends in the anus. A pair of excretory tubules of perforated cells, ciliated internally, opens to the outside by the ***excretory pore.*** The upper hemisphere of the larva is distinguished as the ***velum*** from the lower, the ciliated band is the ***velar band*** or ***velar ring.*** The trochophore larva of the Gastropod at this stage is called ***veliger larva.*** The veliger now develops the rudimentary ***foot*** between the mouth and anus. The ***shell gland*** is a patch of columnar cells of the ectoderm on the dorsal surface of the veliger.

Instead of elongating and segmenting as in the trochophore of the Annelid, the mesoblast bands on the right and left of anus of the veliger become hollow. Their cavities are the ***coeloms.*** The left coelom degenerates but the right coelom increases in size and gives rise to the pericardium, the excretory and reproductive organs of the adult. The shell gland gives rise to the larval shell that grows enormously. The mouth of the shell is surrounded by thickened patch of the body wall, the ***mantle.*** The anus moves to the ventral surface and finally comes to open near the mouth. In the bilaterally symmetrical larva the foot grows in size, the velum becomes reduced and the paired tentacles develop. The thickened edge of the mantle secretes the permanent shell. The visceral mass now becomes spirally coiled and the shell falls by its own weight to the right side, resulting in the asymmetry of the young gastropod.

CEPHALOPODA

The CEPHALOPODA are the most highly developed of the molluscs. They have a large ***head*** that bears conspicuous ***eyes.*** The mouth is surrounded by 8—10 fleshy ***tentacles*** or arms. The body is elongate dorsoventrally and the head is ventral. The arms are the modified foot. In the anterior wall of the body there is a horny ***internal shell*** (the common 'seafroth'). A cartilage-like case surrounds the ***brain*** The ***mantle*** is conical and alternately contracts and expands and forcibly expels the water out of the ***siphon.*** The result of this jet is the

the muscles. Hence it is called ***exoskeleton*** or outer skeleton (Fig. 209)

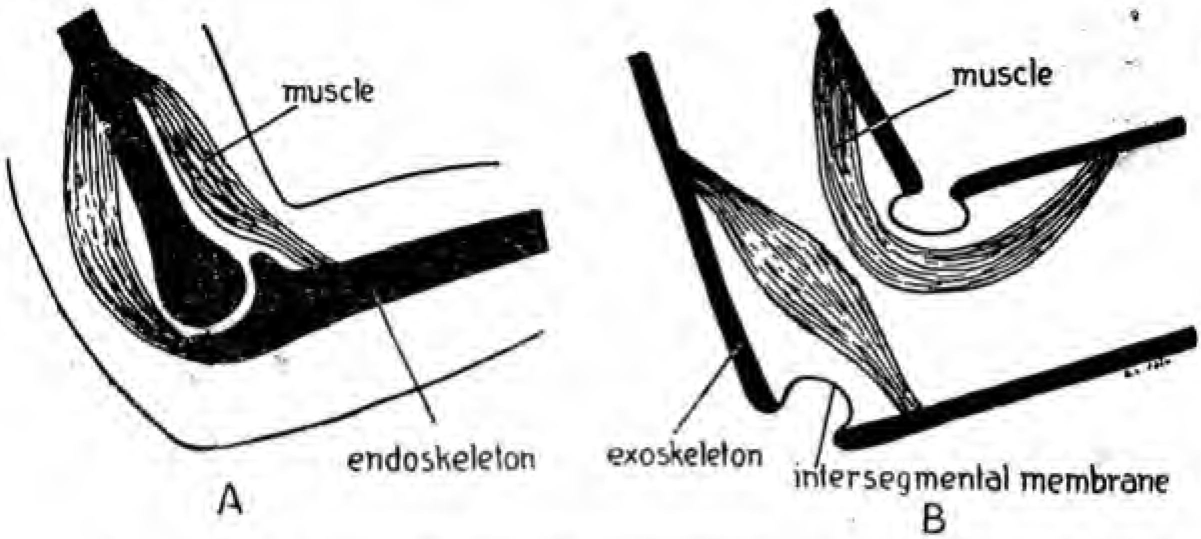


FIG. 209. Diagram to illustrate the fundamental differences between A. endoskeleton comprising bones covered by muscles as in the human hand B. exoskeleton comprising plates of hardened outer body wall connected by soft intersegmental membranes and covering the muscles as in the leg of an insect. The one lies within and the other on the surface of the body.

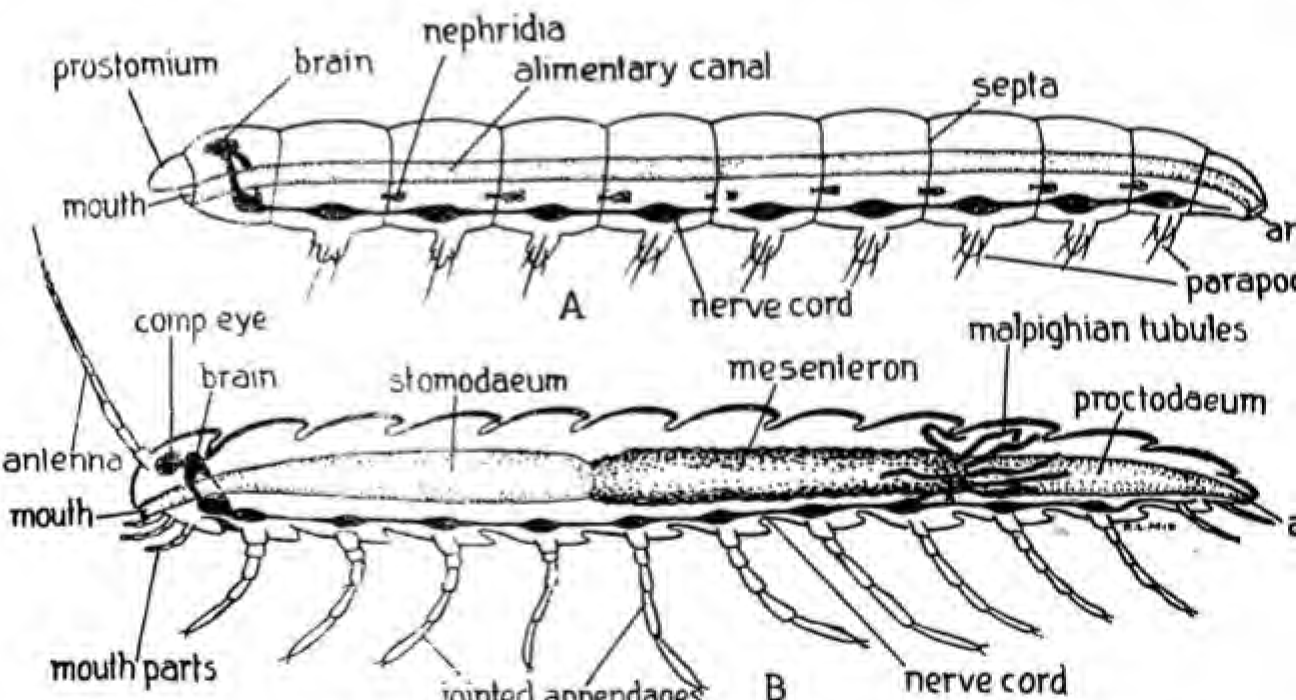


FIG. 210. Ideal diagram illustrating the fundamental difference in the annelidan-arthropodan plans of body structure: A. external and internal metamerism, soft body wall, circumpharyngeal nerve ring, ventral nerve cord, segmental nephridia and unjointed parapodia in the annelid; B. only external metamerism, exoskeleton of regionally hardened body wall, jointed appendages, circumpharyngeal nerve ring and ventral nerve cord and Malpighian tubules in the Arthropods.

ring aerial respiration the blood from the perivisceral sinus largely /s into the pulmonary sac and little into the gill through renal chamber. aquatic respiration reverse is the case. When the snail is submerged der water, true aquatic respiration takes place. The ctenidium is the ;an of aquatic respiration. It lies in the right mantle cavity and consists a series of thin triangular plates attached along a single row to the axis. ıe ***pulmonary sac*** is concerned in aerial respiration. It is a large, ghly vascular pouch that hangs from the roof of the mantle cavity. lternate contractions and expansions of the pulmonary sac bring about ,spiration and expiration.

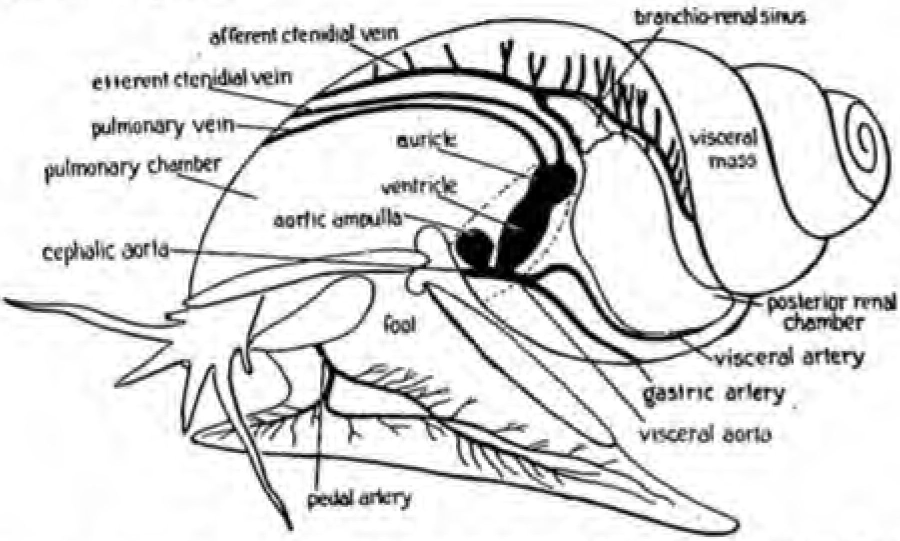


FIG. 203. *Pila globosa*. Circulatory system. (*Adopted from Baini Prashad, 1925, Mem. Indian Museum, 8*).

The excretory organ consists of two chambers: the ***right anterior*** and the ***left posterior.*** The right anterior chamber projects into the mantle cavity, into which it opens. The posterior chamber lies behind the anterior and to the left of the rectum. The pericardium that lies on the left of this chamber is separated by thin septum, which is perforated by the ***reno-pericardial pore.***

The sexes are separate. The male is somewhat smaller than the female. The male genital organs include 1. the testis with vasa efferentia, 2. the vas deferens with the seminal vesicle, 3. the hypobranchial gland and 4. the penis and its sheath. The ***testis*** is a flattened triangular plate in the $2\frac{1}{2}$—3rd whorl of the shell. Several fine ***vasa efferentia*** emerging from the testis, unite or open into the ***vas deferens.*** The vas deferens comprises a thin tube that enlarges into a ***vesicula seminalis*** for storage of semen. Before it ends near the anus the vas deferens is developed into a

External features.—The body of the snail is divisible into a ***head,*** a ***foot*** and a ***visceral mass.*** When the body is extended, the visceral mass always remains within the ***spiral shell.*** When disturbed, the entire body is withdrawn into the shell, the mouth of which is closed by a calcareous ***operculum.***

The globose ***shell*** consists of six and a half ***whorls,*** that increase in size from the ***summit*** to the ***base.*** The whorls are in close contact with

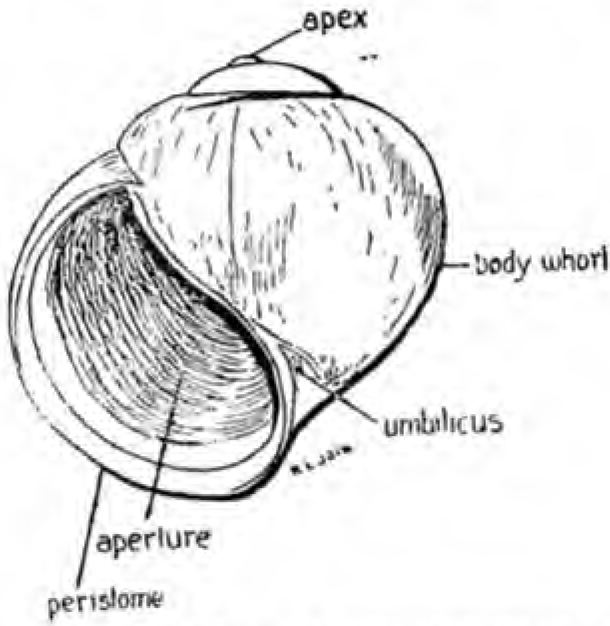


FIG. 201. *Pila globosa.* A sinistral shell in front view.

one another and each lower whorl is larger and overlaps the one above to a great extent. The lines of junction between the whorls constitute the ***sutures.*** The ***cavity*** of the shell is continuous. The ***axis*** of the spirally twisted shell is occupied by a spirally twisted central ***columella,*** which opens below by a narrow ***umbilicus.*** The lowermost whorl is the largest and is called the ***body whorl.*** The opening of the shell is called the ***aperture.*** The outer border or lip of the aperture is the ***peristome.*** The inner lip is formed by the body whorl and columella. At the apex the first whorl ends in a small rounded extremity, the ***nucleus,*** which is the oldest part of the shell. The outer surface of the shell is smooth or has ridges corresponding to the lines of growth. The colour is uniformly lemon-yellow, brown or sometimes black. The operculum that plugs the aperture is a calcareous plate.

As in unio, the shell consists of the outer ***periostracum,*** a middle ***prismatic layer*** and the inner ***nacreous*** layer. It increases by addition to its aperture. If it is held with the apex above and the aperture

GASTROPODA

The GASTROPODS have a distinct bilaterally symmetrical head and an elongate ventral foot but the visceral mass is spirally coiled. The shell is spirally coiled and unchambered; it is ***univalve***. The shell exhibits great variety of form: in most forms the shell is right-handed but in some left-handed. The gastropods are abundant in the sea, fresh-water and on land. They are classified as follows:

Subclass 1. PROSOBRANCHIATA. (=Streptoneura). Nervous system 8-shaped. Shell large, thick, usually with calcareous operculum. Head often snout like. Gills anterior to the heart. Mostly marine. Examples: *Acmaea*, *Patella*, *Fissurella* the limpet, *Haliotis* the abalone, *Crepidula* boatshell, *Littorina*, *Strombus* the conch, *Cypraea* cowries, *Murex*, *Buccinum*.

Subclass 2. OPISTHOBRANCHIATA. (=Euthyneura). Nervous system not twisted in the figure of 8. Shell small or none. Body asymmetrical or secondarily symmetrical. Gill generally present, posterior to the heart. All marine. Examples: *Tethys*, *Doris*, *Aeolis*.

Subclass 3. PULMONATA. (Euthyneura—part). Mantle cavity anterior and modified into a lung, opening on the right side. Shell a simple spiral or none. No gills. Examples: *Planorbis*, *Helix* the garden snail, *Limax* the slug.

2. PILA

Pila globosa, the common apple snail, is abundant in tanks, ponds and ricefields. It prefers clean waters in which succulent aquatic plants flourish. During summer it lies buried in the mud, with the shell closed tight by the ***operculum***. During rains it frequently leaves the ponds and crawls for long distances. A sticky secretion from the foot leaves a glistening track behind. When disturbed it withdraws into its spirally coiled shell. Its food consists of leaves of various kinds of plants.

Systematic position.—

Phylum MOLLUSCA
Class *GASTROPODA*
Subclass PROSOBRANCHIATA
Order *Pectinibranchiata* (=*Monotocardia*, with a single auricle)
Suborder Taenioglossa
Family Ampullariidae
Genus *Pila*
Species *globosa*.

Its range of distribution extends from Bombay to Assam in the Indo-Gangetic plain. Its place is taken by *Pila virens*, *Pila conica* and *P. theobaldi* in South India.

thick glandular part. The ***penis sac*** is an outgrowth from the mantle. The ***penis*** arises from a flap of the mantle. It is a rod-like structure with a deep groove on the inner surface. The female genital organs include 1. the ovary, 2. the main oviduct, 3. seminal receptacle, 4. the uterus, 5. the vagina and 6. the hypobranchial gland with rudimentary copulatory apparatus. The ***ovary*** occupies the same position as the testis of the male. The ***oviduct*** lies below the ovary. The ***seminal receptacle*** is a bean-shaped body below the posterior renal chamber and to the left of the uterus. The ***uterus*** is a large, deep yellow, pyriform structure that continues as the ***vagina***. The seminal receptacle opens into it.

The nervous system.—Paired ***buccal ganglia***, one on each side dorsolaterally on the buccal mass at the junction of the oesophagus, are connected together by the stout ***buccal commissure*** below the oesophagus. The buccal ganglia innervate the buccal mass and oesophagus. The buccal ganglia of each side is connected by a ***cerebrobuccal connective*** to the ***cerebral ganglion*** of its side.

The cerebral ganglia are paired structures lying anteriorly on the dorsolateral side of the buccal mass. A ***cerebral commissure*** running transversely above the buccal mass connects the ganglia of the two sides. The cerebral ganglia innervate the snout, labial palps, tentacles, eyes and statocysts. The cerebral ganglion of each side is connected to the corresponding ***pleural*** and ***pedal*** ganglia by ***cerebropleural*** and ***cerebropedal*** connectives. The pleural and pedal ganglia are fused together into a rectangular composite ***pleuropedal*** ganglion. The pedal portions of the composite mass of the two sides is inter-connected by two transverse ***pedal commissures***. The pedal ganglion sends out a large number of nerves to the foot.

The left pleural ganglion is connected to the right pleural ganglion by the ***infra-intestinal nerve***. A ***pleurocerebral*** connective from the left pleural ganglion connects with the corresponding cerebral ganglion. It innervates the osphradium, parietal wall and other nearby structures. The right pleural ganglion differs from the left in having the ***subintestinal ganglion*** fused with it. A stout ***pallial nerve*** arises from it. A thin ***supra-intestinal nerve*** connects it to the ***supra-intestinal ganglion*** behind the pleuropedal ganglionic mass. The supra-intestinal ganglion is a fusiform mass behind the pleuropedal. It innervates the mantle, the gill, pulmonary sac, etc. It connects with the pleural ganglion by the supra-intestinal nerve. Posteriorly it is connected by the ***visceral connective*** to the ***visceral ganglion***.

The visceral ganglia are two fused masses at the base of the visceral mass, close to the anterior lobe of the digestive gland. It innervates the renal and genital organs, intestine, stomach, digestive glands, etc.

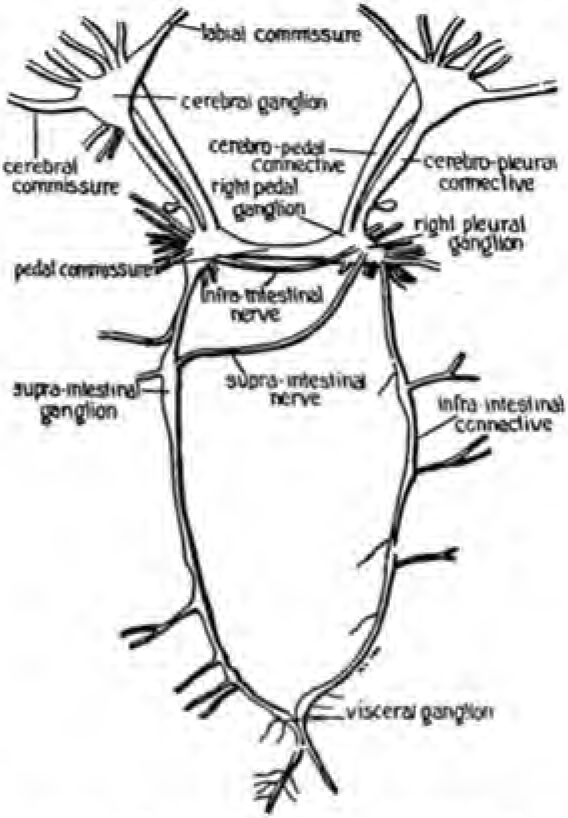


Fig. 204. *Pila globosa.* Nervous system. (*Adopted from Baini Prashad, 1925, Mem. Indian Museum, 8*).

The sense organs include the osphradium, the eyes, statocysts, tentacles and labial palpi. The ***osphradium*** is situated dorsolaterally on the roof of the mantle cavity. It hangs in the respiratory current like a curtain and is probably of olfactory nature. The ***eyes*** are two deep black spots situated on short stalks behind the true tentacles. Each eye is a closed vesicle lined by epithelium, which is transparent in front, but modified into a retina behind. The cavity of the vesicle is occupied by a transparent circular lens. The ***statocyst*** (otocyst) is an organ of equilibrium, found close to the pedal ganglion. Each has a minute calcareous ***statocornia*** floating in a fluid.

Development of Gastropod.—The following is a brief account of the development of a typical marine Gastropod, without reference to any particular species. It should serve as a type of Gastropod embryology.

II. Unio

4. *Unio* is a common fresh-water mussel that has a bivalve shell. The valves consist of a periostracum and a prismatic and nacreous layer. They are kept closed by the powerful adductor muscles.

5. The mantle and the gills are the organs of respiration.

6. The circulatory system includes a three-chambered heart, the ventricle of which surrounds the rectum.

7. The nervous system comprises cerebropleural, pedal and visceral ganglia connected by nerves.

8. The sense organs include the statocyst and osphradium.

9. The sexes are separate. During development a glochidium larva lives as an ectoparasite on the gills of fish before the young unio is formed.

III. Pila

10. *Pila* is a common fresh-water snail. Its body comprises a head, a spirally coiled visceral mass, a muscular foot and mantle, all of which can be retracted into a spiral shell and the mouth of the shell closed by a calcareous operculum.

11. The alimentary canal includes a large buccal mass containing the radula which serves as the rasping organ.

12. The heart comprises a single auricle and ventricle.

13. Respiration is both aquatic by means of gills and aerial by means of pulmonary sac.

14. The nervous system consists of a ganglionated ring around the buccal mass connected to the pleuropedal and visceral ganglia. There is partial concentration of the nervous system. The sense organs are eyes, statocyst and osphradium.

15. During development a veliger larva, greatly resembling an Annelid trochophore, gradually metamorphoses into the snail.

chambers, retina with rods very much like those of Vertebrates. The Cephalopods are all free-swimming and predaceous. They are classified as below :

FIG. 207. Phylum Mollusca. Class Cephalopoda. In nearly all the living forms the shell is degenerate and concealed within the body. They also have a peculiar funnel that serves as the organ of locomotion : locomotion is effected on the principle of jet-propulsion by forcibly ejecting the water from the funnel. Order Octopoda : *Octopus* often attains a total span often to thirty feet and feeds mainly on crabs. Order Decapoda : *Sepia*, the common cuttlefish has a pair of prehensile tentacles. (*Original photograph of specimens in the Zoology Museum, St. John's College, Agra*).

Subclass 1. TETRABRANCHIA. Shell internal and coiled in one plane, divided into chambers by internal septa. Gills two pairs. No ink sac. Examples : *Ammonites* (extinct), *Nautilus* the pearly nautilus (Figs. 194, 206).

Subclass 2. DIBRANCHIA Shell internal, reduced or none. Arms 8—10, with suckers. Gills one pair. Ink sac present. Examples: *Sepia* cuttlefish (Fig. 207), *Loligo* the squid, *Octopus* (Fig. 207).

RESUMÉ

I. Mollusca

1. The Mollusca are triploblastic unsegmented animals typically with a mantle, a visceral mass and a muscular foot and enclosed in a calcareous shell secreted by the mantle.

2. They are divided into the Amphineura, Scaphopoda, Pelecypoda, Gastropoda and Cephalopoda.

3. The Amphineura have a generalized nervous system. Their shell consists typically of eight dorsal plates. The Scaphopoda have a tube-like shell open at both ends. In the Pelecypoda there is no head and the shell is composed of two valves. The Gastropods posess a well defined head with eyes ond tentacles and the body is spirally coiled. The shell is also spiral. The Cephalopods are the most advanced of the Mollusca. They have no true foot but only tentacles. Their eyes resemble those of Vertebrates. The shell is often chambered or internal.

Successive unequal cleavages of the zygote (Fig. 205) result in the formation of a group of ***micromeres*** and four ***macromeres***. The former continue to divide more rapidly than the latter and a hollow ***blastula*** is thus formed. The micromeres constitute the roof of the blastula and the four macromeres form its floor. The macromeres now divide and become ***invaginated*** or folded inward into the ***blastocoele***, the cavity of the blastula. A double-layered ***gastrula*** results. Two cells derived

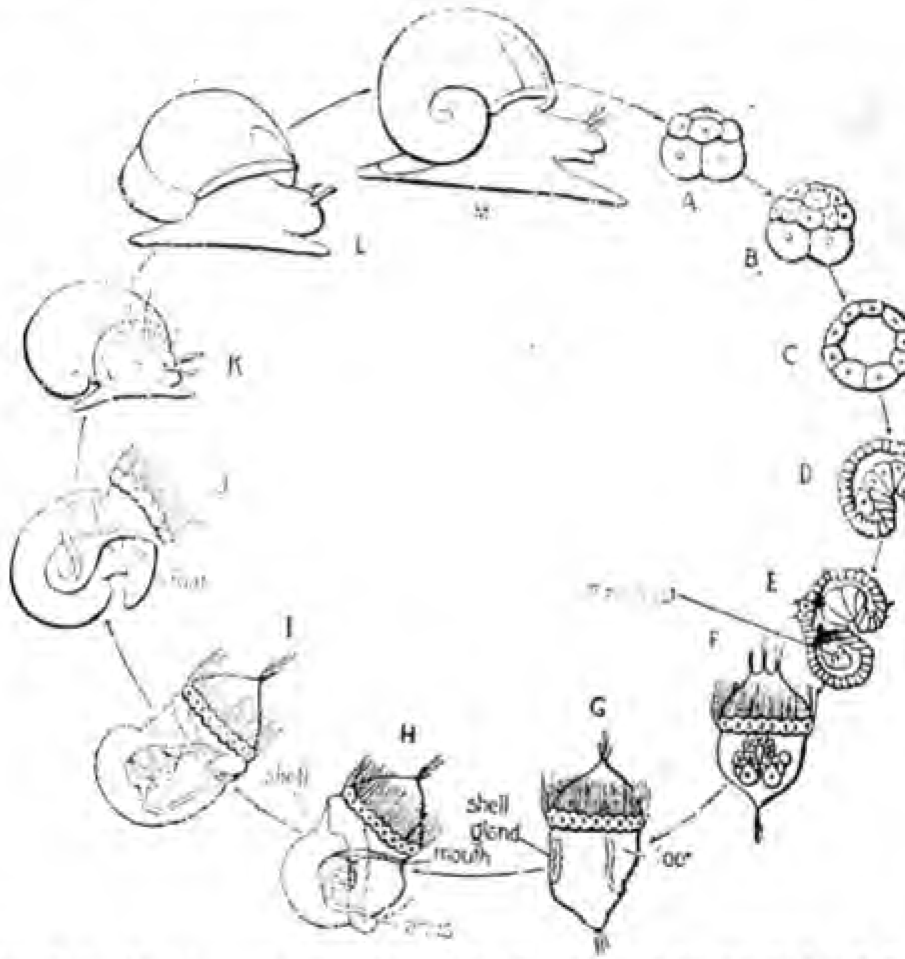


FIG. 205. Development and life-cycle of a typical Gastropod. A-B. Cleavage. C. Blastula in section. D-E. Gastrula in section. F-G. Veliger larva with shell gland and rudimentary foot. H. Veliger with shell and commencement of torsion. I-J. Torsion of the visceral mass. K-L. Young snails. M. Adult snail.

from the macromeres migrate into the blastocoele at what is destined later on to become the posterior end of the future snail. These are the ***mesoblasts*** as in the earthworm. The mesoblast cells repeatedly divide and give rise to a double-layered band between the ectoderm and the endoderm. The ectoderm cells near the equator of the gastrula become elongated and develop tufts of cilia. One or more such ciliated bands girdle the embryo. An *apical tuft* of cilia often develops on

The Annelida and the Arthropoda are both segmented animals, hout notochord and with the nervous system ventral to the alimentary ial. The Arthropods differ from the Annelids in 1. the absence of ia, 2. absence of inter-segmental septa, 3. reduction of excretory gans and gonads, 4. presence of jointed appendages, 5. exoskeleton, separation of the sexes, 7. presence of compound eyes and 8. presence a definitive head.

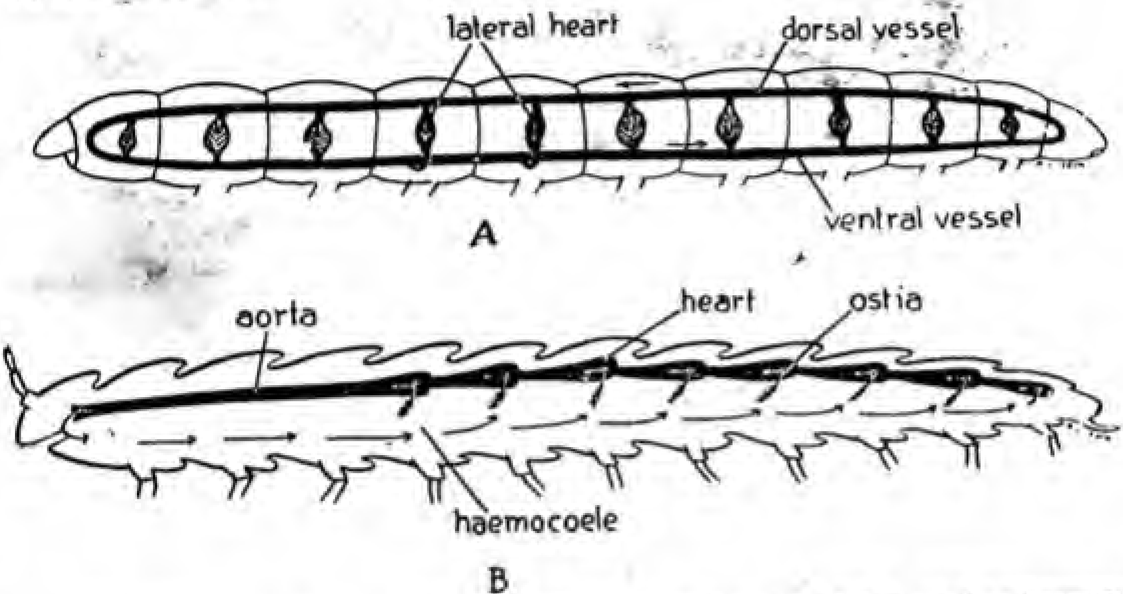


FIG. 211. Ideal diagram of the differences in the annelidan and arthropodan circulatory systems: A. closed circulation in the Annelid and B. open circulation in the Arthropod.

Characters.

1. Body bilaterally symmetrical, triploblastic and metamerically segmented.
2. Body segments modified and specialized into various regions like head, thorax or abdomen.
3. Paired jointed or segmented appendages typically to each segment of the body.
4. Exoskeleton of chitin.
5. Striated muscles.
6. Complete alimentary canal with mouthparts for biting, chewing, piercing, sucking, etc.
7. Circulatory system not closed.
8. Respiration by gills or special tubes.
9. Excretion by green-glands or malpighian tubules.
10. Nervous system of the Annelidan type.
11. Sense organs include compound eyes and sound perceiving organs.
12. Sexes separate and fertilization internal.
13. Cleavage superficial.
14. Development often with metamorphosis.

The nervous System with paired
and double nerve cords

Characters common to the Annelida and Arthropoda

1. Metameric segmentation of the body.

2. Lateral extensions of the segments of the body into processes that subserve locomotion, viz. parapodia and appendages.

3. Ventral nerve and anterior nerve-ring surrounding pharynx or oesophagus.

4. Dorsal heart

Characters peculiar to Annelida

1. Body wall soft and sometimes chitinous.
2. Mouth in the first segment.
3. Coelom cavity in each segment.
4. Tentacles on prostomium.
5. Parapodia never modified as jaws and never segmented.
6. Intersegmental septa present.

Characters peculiar to the Arthropoda

1. Body wall chitinous and very often hardened by deposit of variou materials, including lime salts.

2. Mouth shifted to the third segment.

3. Body cavity is not coelom, which is reduced to haemocoels.

4. Segments with segmented appendages that are modified as feelers jaws, legs, gills or claspers.

5. Intersegmental septa absent.

Classification.—There is much disagreement regarding the classes into which the Arthropods are subdivided. Some recognize five while others list thirteen classes.

Phylum ARTHROPODA

Class 1. CRUSTACEA. Exoskeleton hardened by deposit of lime; modern forms with two pairs of antennae; mostly aquatic, respiration by gills. Examples: crab, prawn, waterfleas, barnacles, etc.

Class 2. PYCNOGONIDA. Marine; abdomen vestigial; suctorial proboscis; legs seven pairs; male carries eggs. Example: sea-spider. (Fig. 213).

Class 3. XIPHOSURA. Marine; abdominal segments fused, ending in a long spine; large cephalothorax. Example: *Limulus* king-crab, (Fig. 212).

Class 4. ARACHNOIDEA. Terrestrial; four pairs of legs; abdomen without legs; simple eyes. Examples: spider, scorpion, mite, ticks, whip-scorpion, book-scorpion. (Figs. 212, 214, 215).

Class 5. DIPLOPODA. Terrestrial; numerous segments with two pairs of legs. Example: *Julus*. (Fig. 217).

Class 6. PAUROPODA. Nine pairs of legs; terrestrial without eyes; found under logs, stones, etc. in damp places. Example: *Pauropus*.

Class 7. SYMPHYLA. Terrestrial; without eyes; twelve pairs of legs; in damp places. Example: *Scolopendrella*.

Class 8. CHILOPODA. Terrestrial ; body flattened, with one pair of legs to each segment. Examples : *Geophilus*, *Lithebius* centipedes, *Scutigera* house centipedes. (Fig. 216).

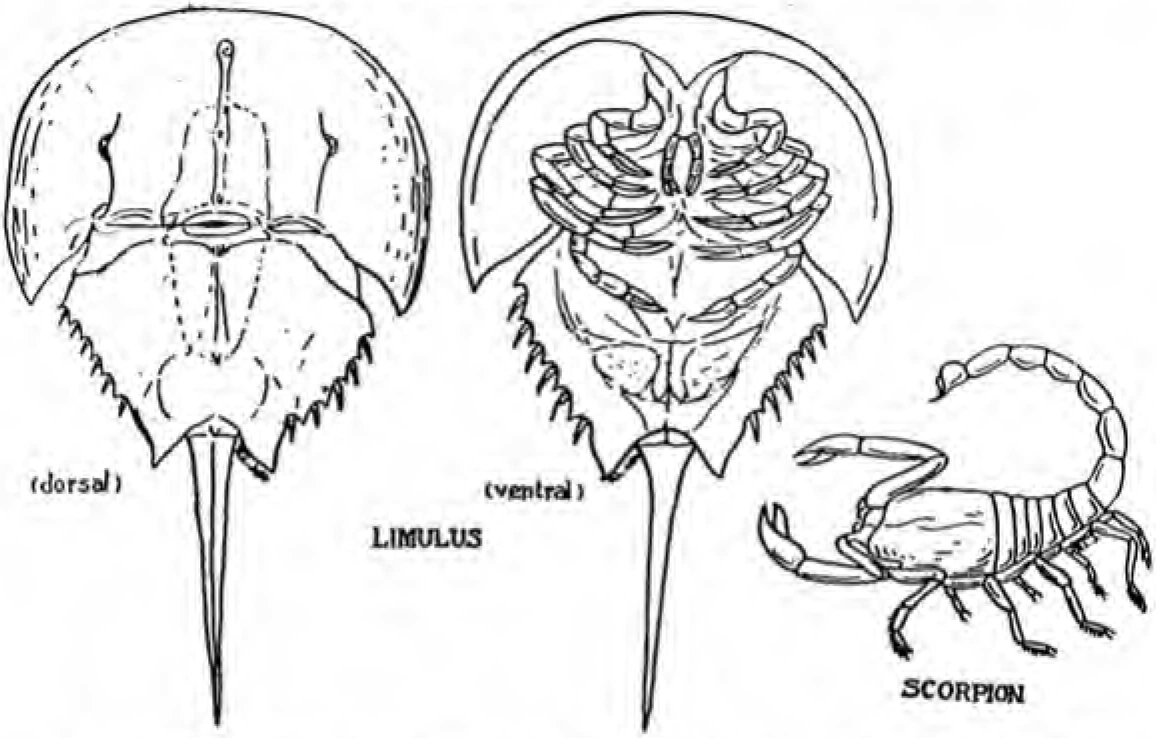


FIG. 212. phylum Arthropoda. Class Xiposura ; *Limulus* the kingcrab is a giant member of the Class Xiphosura. It is an inhabitant of the sea and spends most of its life burrowing in sand. It feeds on shell-less molluscs and worms. It is a survival of the great past. Class Arachnoidea : Scorpions were the first Arthropods to invade dry land. They love to hide during the day and hunt their prey at night. Any small insect or spider is seized, torn to pieces and if needed paralyzed by the sting. They are murderous wives that kill their husbands after the nuptial but ideal mothers that carry the young on their back.

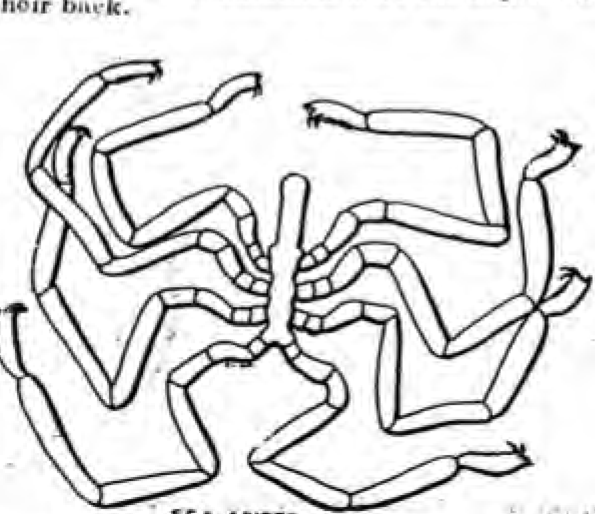


FIG. 213. Phylum Arthropoda. Class Pycnogonida. The sea spider occurs on algae, under stones and other objects in the sea. The male carries the eggs.

Class 9. ONYCHOPHORA. Worm-like; terrestrial, with a pair of antennae and eyes; unsegmented body with stumpy legs Exapmle: *Peripatus.* (Fig. 218).

Class 10. TARDIGRADA. Minute unsegmented legs; four pairs unsegmented and with two or more claws ; under moss, in water, etc. Example : water-bears.

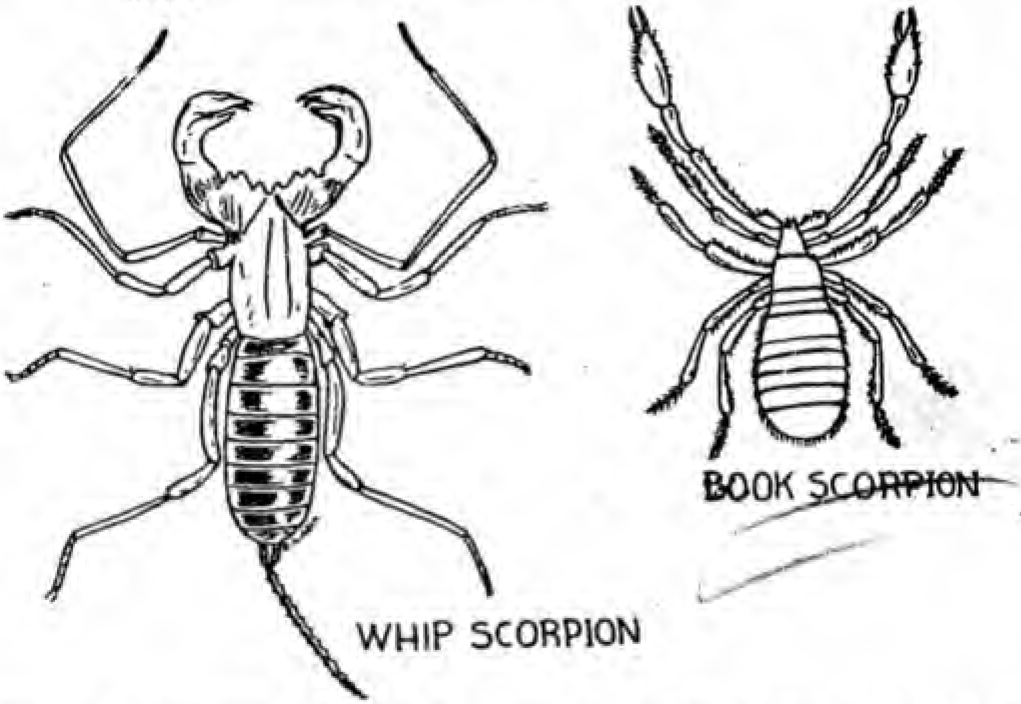


FIG. 214. Phylum Arthropoda. Class Arachnida. Order Pedipalpi. Whip scorpion has a terminal whip on the abdomen and strong pedipalps. Order Pseudo-scorpionida : Book scorpion is no scorpion, and has no sting. It lives in damp old buildings and on moss.

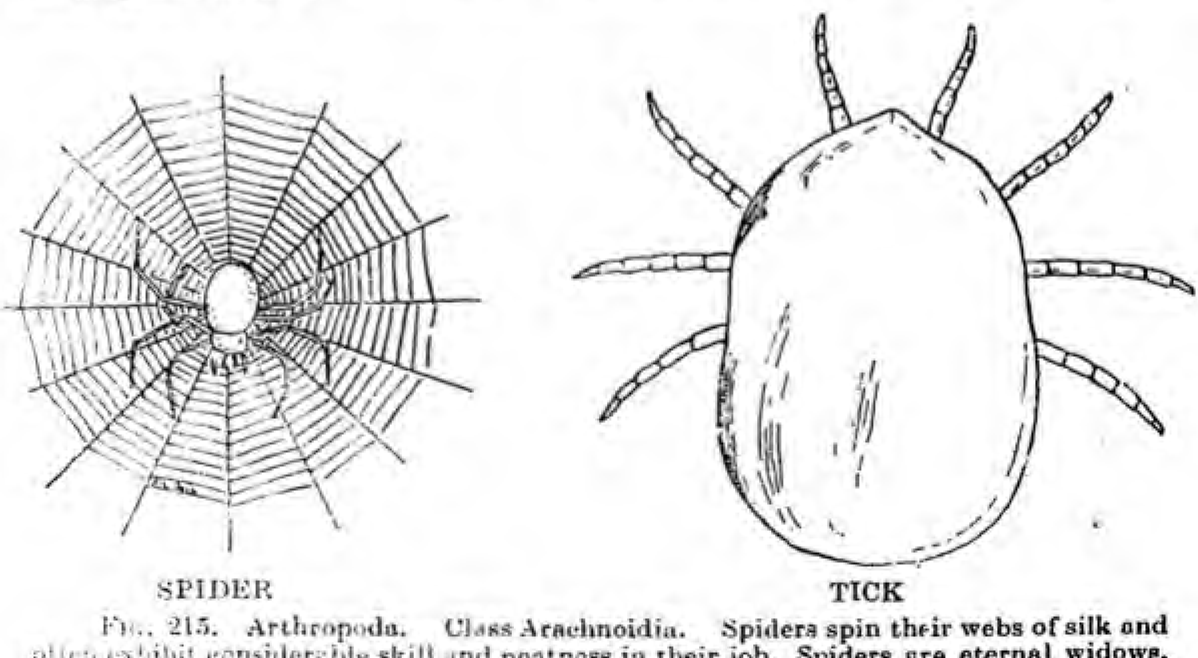
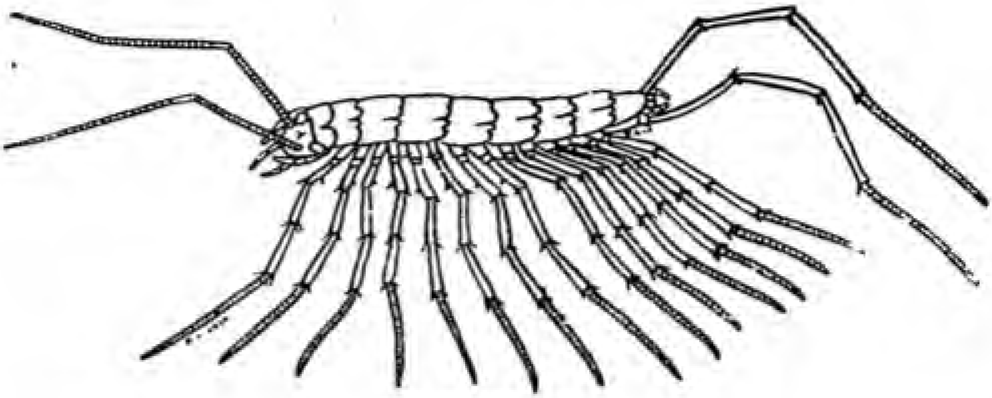
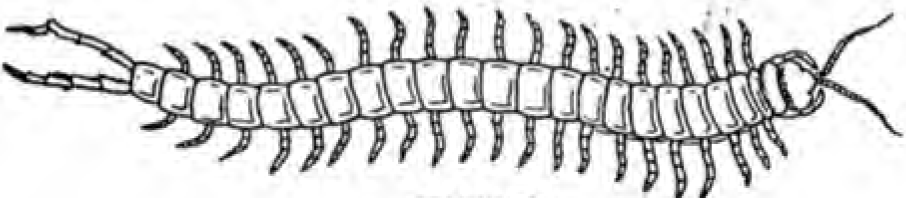


FIG. 215. Arthropoda. Class Arachnoidia. Spiders spin their webs of silk and often exhibit considerable skill and neatness in their job. Spiders are eternal widows, because they kill and devour the husband directly after the nuptial. They are mostly beneficial to man. Ticks are ectoparasites on various animals like cat, dog, cattle, etc. on whose blood they live.

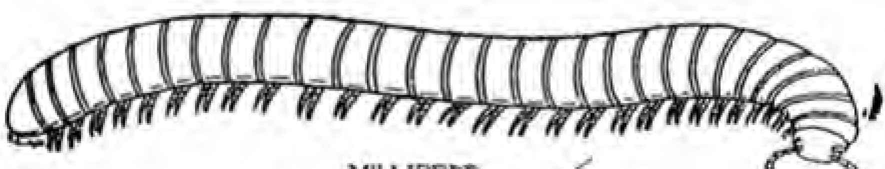


SCUTIGERA

FIG. 216. Phylum Arthropoda. Class Chilopoda : Scutigera the house centipede has 15 pairs of long legs. It runs swiftly and lives on all sorts of small insects.



CENTIPEDE



MILLIPEDE

FIG. 217. Phylum Arthropoda. Class Chilopoda : Centipedes live under leaves and feed on insects, that are seized by the poison fangs and stung. Some are phosphorescent and glow in darkness. Class Diplopoda: Millipedes differ from Centipedes in not having poison fangs. They feed on underground parts of plants. Many secrete hydrocyanic acid by stink glands, as a protective device.

PERIPATUS

FIG 218. Phylum Arthropoda. Class Onycophora : *Peripatus*.

Class 11. PENTASTOMIDA. Unsegmented, worm-like, parasitic in liver and lung of rabbits, nose of dog and rarely man. Example : tongue-worms.

Class 12. INSECTA. Head, thorax and abdomen distinct; single pair of antennae, three pairs of legs and usually one or two pairs of wings on thorax; no legs on abdomen. Respiration by tracheæ. The most dominant class of animals that have evolved social life. Three quarter of a million species known. Examples : cockroach, grasshopper, bugs, beetles, dragonflies, butterflies, moths, ants, bees, wasps, termites, etc., etc.

CRUSTACEA

The CRUSTACEA (*crust* hard shell) include the crabs, prawns, crayfishes, waterfleas, fairy-shrimps and barnacles. They are mostly marine but some inhabit fresh-waters. Respiration is by gills. A few like the sow-bugs terrestrial. The cuticle of the integument is hardened by

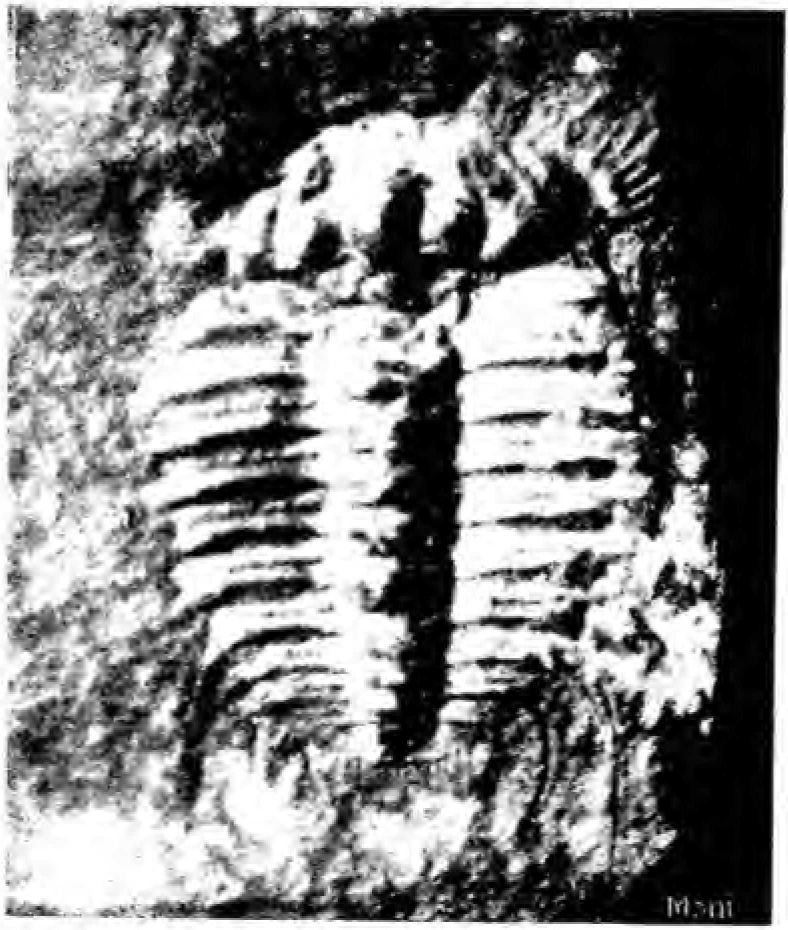


FIG. 219 Phylum Arthropoda. Trilobite, an extinct Crustacean (*Original photograph of a fossil in the Zoology Museum, St. John's College, Agra.*)

addition of carbonate and phosphate of calcium. The appendages are typically biramous, i.e. branched into two. All modern Crustacea have two pairs of antennae or feelers on the head. A shield called carapace extends back from the head and covers part of the rest of the body.

Characters.—

1. Head with two pairs of antennae, one pair of mandibles and two pairs of maxillae.
2. Carapace covers head and parts of thorax.
3. Respiration by gills.
4. Excretion by "green-glands"; no malpighian tubules.

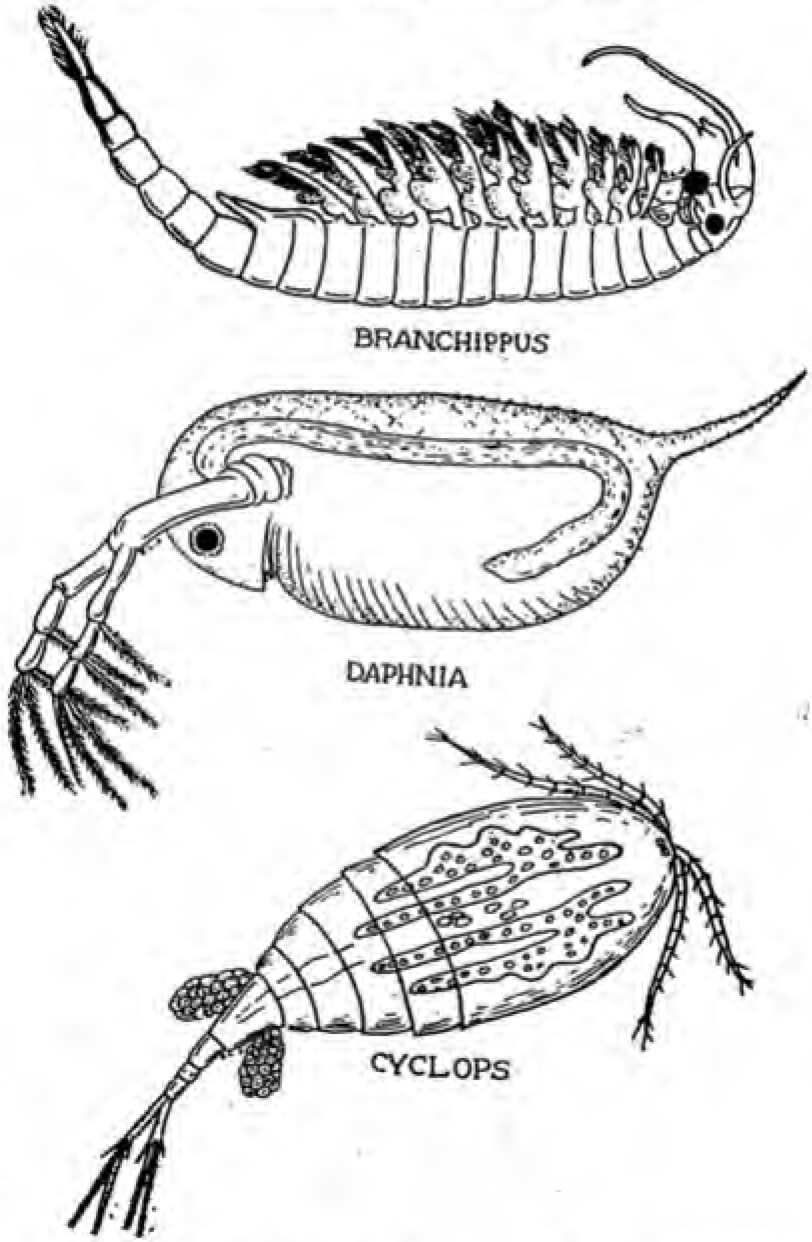


FIG. 220. Phylum Arthropoda. Class Crustacea. *Branchipus* the fairy-shrimp swims upside down in fresh-water ponds. *Daphnia* the common waterflea is abundant in all stagnant fresh-water. It is a very small transparent crustacean with a bivalve shell and long antennae that are used in locomotion. *Cyclops* is a common fresh-water copepod.

5. Genital openings paired.
6. Development with more or less of metamorphosis.

Classification.—

Phylum ARTHROPODA

Class *CRUSTACEA*

Subclass 1. TRILOBITA. Extinct marine forms, with the body in three longitudinal lobes and single pair of antennae; known as fossils only. Example: *Triarthrus*. (Fig. 219).

Subclass 2. BRANCHIOPODA (=Phyllopoda). With leaf-like appendages; mostly fresh-water forms. Examples: *Branchipus* fairy-shrimp, *Daphnia*.

Subclass 3. COPEPODA. Carapace absent; abdomen without appendages; many parasitic. Example: *Cyclops* waterflea. (Fig. 220).

Subclass 4. OSTRACODA. Carapace bivalved and covering the whole body. Example: *Cypris*.

Subclass 5. CIRRIPEDIA. Adult sessile, enclosed in calcareous plates. Examples: *Balanus* acorn barnacle, *Lepas* goose barnacle. (Fig. 220.)

Subclass 6. MALACOSTRACA. Segments 19; head fused to one or more segments; appendages on all segments. Examples: *Squilla*, *Palaemon* prawn, *Cancer* crab, *Oniscus* sow-bug.

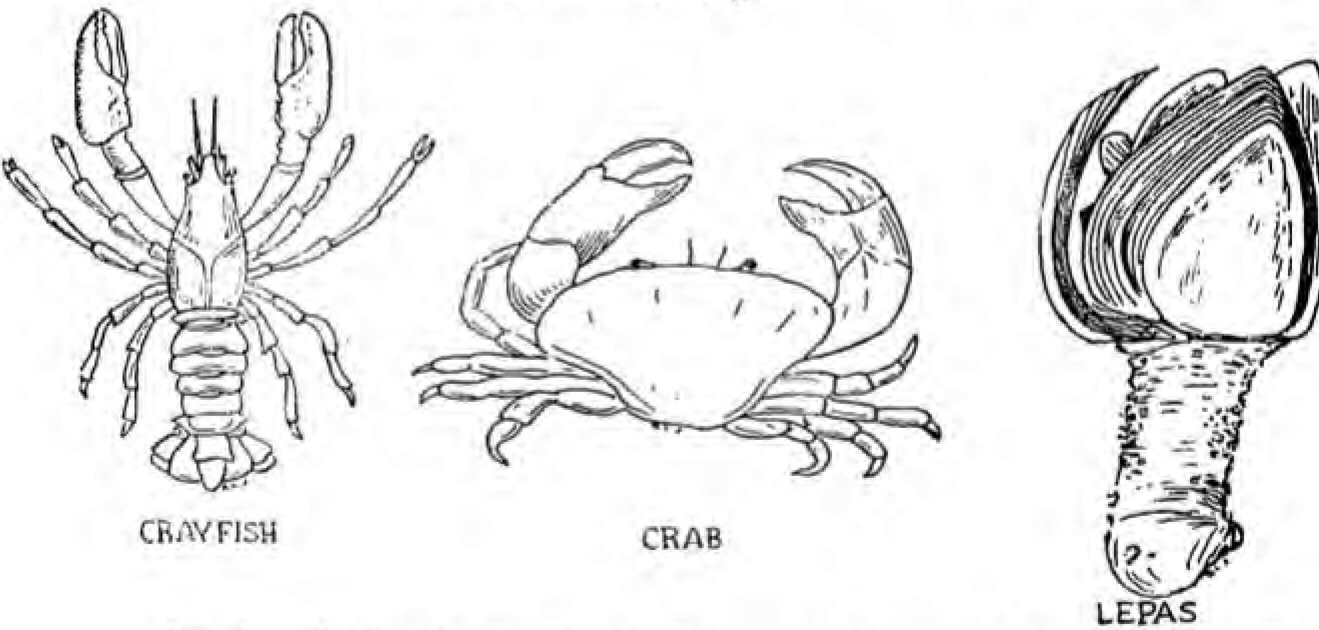


FIG. 221. Phylum Arthropoda. Class Crustacea. Crayfish and crab are common Decapod Crustaceans, that have the anterior pair of legs modified as pincers. *Lepas*, the common goose barnacle, is free as larva but becomes fixed, enclosed in shelly plates and kicks the food into mouth by its legs. Barnacles often attach themselves to ships in great numbers and reduce the ship's speed.

THE PRAWN

Prawns and crayfishes are common all over the world. They inhabit fresh-water streams, rivers and ponds hiding by day and coming to the surface by night. They form an important article of food for man. There are several species of prawns in India. The common river prawn belongs to the genus *Palaemon*, Order Decapoda with ten walking legs, subclass Malacostraca.

External features.—The body comprises a rigid ***cephalothorax*** in front and a mobile ***abdomen*** behind. The abdomen is composed of six free segments and the cephalothorax of fourteen segments fused indistinguishably together. Each segment has a pair of ***jointed appendages***. The cephalothorax is covered by a continuous shield or the ***carapace***, above and at the sides. The anterior end of the carapace is produced as a pointed ***rostrum***. Beneath the rostrum on either side is a compound eye on a movable stalk. The slit-like mouth opens ventrally at the anterior end and the anus is a longitudinal slit ventrally at the posterior end, lying beneath a ***telson***. Paired ***renal*** apertures open on the inner surface of the ***antennae***. The paired

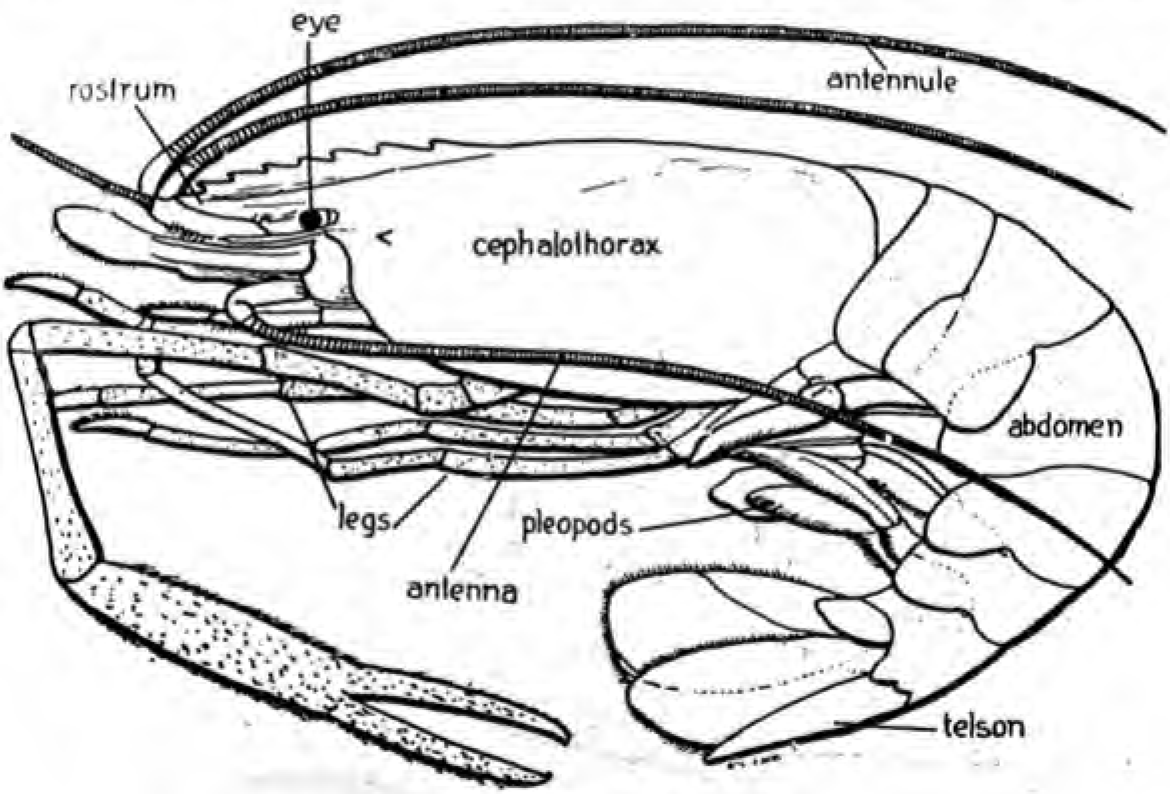


FIG. 222. The prawn. External features.

female genital apertures are located between the third pair of walking legs in the female. The ***male genital apertures*** are also paired openings between the fifth pair of walking legs in the male.

Each segment of the abdomen is composed of a dorsal plate of exoskeleton called ***tergum*** and a ventral ***sternum*** joined together at the sides by membranous ***pleuron***. The gills lie beneath the sides of the carapace.

Appendages.—Each segment of the body has one pair of jointed appendages, containing sets of muscles for moving them. The appendages of different segments differ much in size, shape and function, but are all built on the same general plan, viz. a ***biramous*** or two-branched appendage. A typical biramous appendage consists of 1. a ***protopodite*** of two segments, a ***coxopodite*** and a ***basipodite***, 2. an inner ***endopodite*** and an outer ***exopodite*** of variable number of segments. There are ninteen pairs of appendages, thirteen on the cephalothorax and six on the abdomen. The

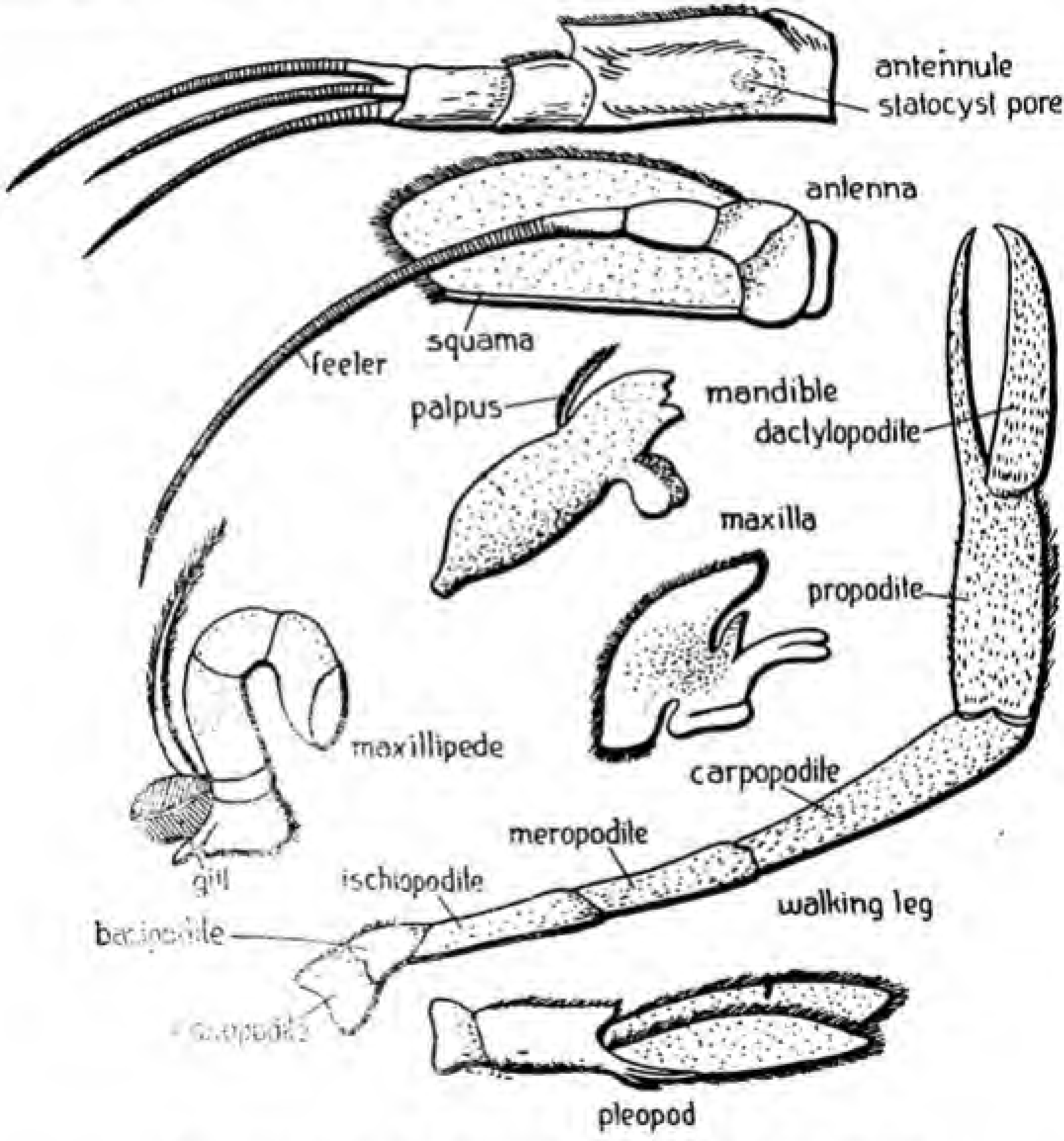


Fig. [illegible]. Some of the typical appendages of the prawn.

cephalothoracic appendages are: 1. ***antennule***, 2. ***antenna***, 3. ***mandible***, 4. ***maxillula***, 5. ***maxilla***, 6. three pairs of ***maxillipedes*** and 7. five pairs of ***walking legs***. The abdominal appendages are called ***pleopods*** or ***swimmerets*** that aid in respiration and also carry the eggs in the female.

The antennule includes three basal ***podomeres*** that comprise the protopodite, an outer and an inner many-jointed feeler. The outer feeler consists of two branches—a short and a long one. The first podomere of the basipodite has the opening of the ***statocyst***. The antenna has the typical two-jointed protopodite bearing the two ***rami*** or branches: a many-jointed whip-like feeler and a flat ***squama***.

The mandible lies one on either side of the mouth and forms the powerful jaws for biting and tearing. On the outer side the mandible bears a triarticulate (with three segements) mandibular ***palpus***.

The ***maxillulae*** are thin leaf-like appendages that have ***gnathobases*** on the protopodite to help the mandible in masticating the food.

The ***maxillae*** are more or less similar to maxillulae. The exopodite is modified into a large fan-shaped ***scaphognathite***, that bales out the water over the gills. The maxillipedes are flattened appendages that bear a leaf-like ***epipodite*** on the coxopodite for use as additional gills.

The ***walking legs*** lack exopodites and comprise seven more or less elongate cylindrical segements: ***coxopodite, basipodite, ischiopodite, meropodite, carpopodite, propodite*** and ***dactylopodite***. The first and second pairs end in pincers, called ***chelae***, used for grasping in offence or defence. These two legs are also used in conveying food to the mouth.

Digestive system.—The mouth is bounded in front by a skeletal plate called ***labrum*** and by a ***metastoma*** behind. The buccal cavity has numerous irregular folds with thick chitinous lining. The oesophagus is a short tube leading behind to a large, thin-walled stomach. The stomach is divided into an anterior large ***cardiac*** stomach and a posterior small ***pyloric*** stomach. The stomach is surrounded by the ***hepatopancreatic glands***, often also called "liver". These glands differ from the liver of the frog, because they secrete all the digestive enzymes and thus combine the functions of gastric, intestinal and pancreatic juices. They also store up glycogen and fat as in the frog but again differ in storing up calcium salts too. Calcified teeth project into the cavity of the cardiac stomach for grinding the food. These teeth are moved by muscles on the outer surface of the stomach. The whole apparatus constitute the ***gastric mill***. A short ***midgut*** follows the pyloric stomach. The midgut continues behind as the intestine ending in the anus. The digested food is sucked back into the hepatopancreatic tubules and absorbed into the system.

Circulatory system.—The blood of the prawn contains leucocytes and a blue respiratory pigment ***haemocyanin*** **:** a compound of copper

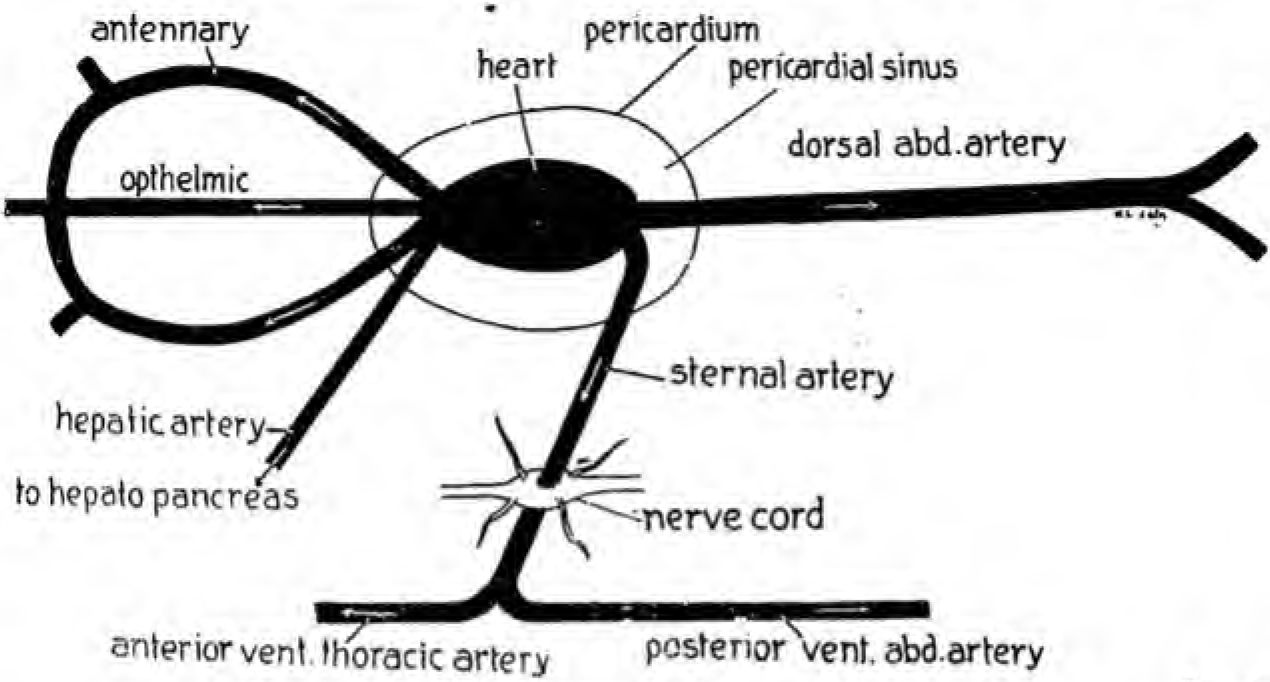


FIG. 224. Circulatory system of the prawn (diagrammatic).

and proteid. The oxygenated blood is bright-blue and the impure blood is colourless. The blood is pumped by a heart into arteries.

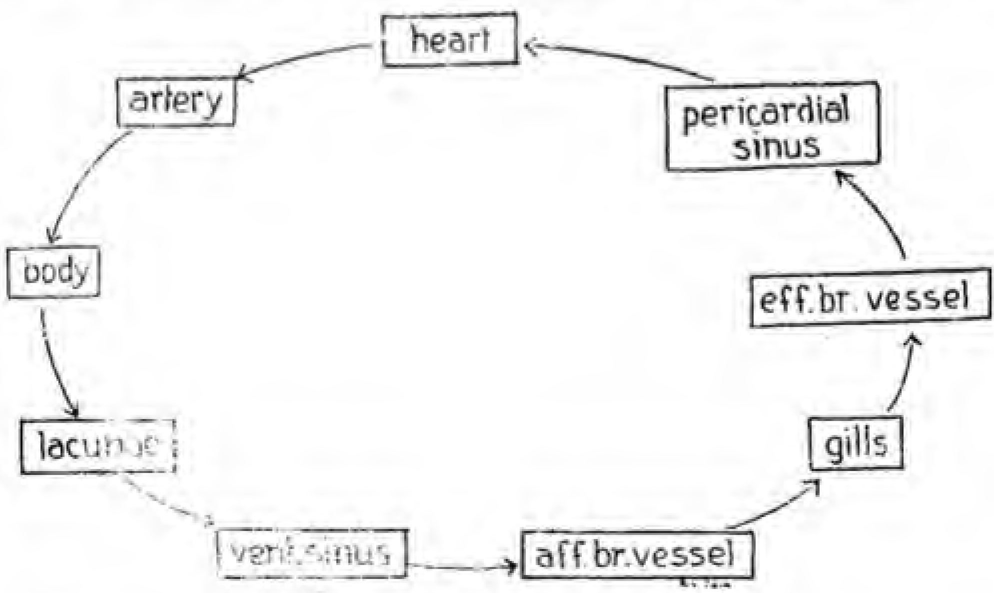


FIG. 225. Diagram of the course of circulation of blood in the prawn.

There are no veins ; the blood escapes into spaces called ***blood lacunae*** or *sinuses*. The circulatory system is thus not the closed type met with in the frog or the earthworm but *open* or ***lacunar*** (Figs. 211, 224, 225).

The circulatory system includes 1. a heart, 2. arteries and 3. blood lacunae or blood sinuses and blood channels. The triangular heart lies in the pericardium with its apex in front, *dorsally* to the aliamentry canal in the posterior part of the cephalothorax. There being no veins, the blood from the pericardial chamber enters the heart through five pairs of slit-like openings called ***ostia.*** Arteries are given off both anteriorly and posteriorly.

The anterior arteries include 1. ***ophthalmic***, 2. ***antennary*** and 3. ***hapatic*** arteries. The median ophthalmic artery runs forward to join the antennary artery. The paired antennary arteries arise on either side of the ophthalmic. Soon afterward, each gives off three branches: ***pericardial***, ***gastric*** and ***mandibular*** arteries. It extends forward to the base of the eyes and divides again into a dorsal and a ventral branch supplying the eye, the antennule and the antenna. The dorsal branch divides again and unites with the fellow of the opposite side to form an arc into which the ophthalmic opens. The paired hepatic arteries originate from the root of the antennary arteries.

The posterior arteries include 1. the ***dorsal abdominal*** or ***supra-intestinal*** and 2. the ***sternal*** arteries. The dorsal abdominal artery is a median unpaired blood vessel running backward dorsad of the intestine. It bifurcates on the end gut. The sternal artery is a stout vessel arising from the root of the dorsal abdominal. It runs downward through the nerve cord to the sternum, where it divides into an anterior large ***ventral thoracic artery*** and a posterior ***ventral abdominal artery***. The former runs forward and gives off branches to the first three pairs of walking legs, maxillipedes, maxillae and maxilluae. The latter runs backward giving off paired branches to the fourth and fifth pairs of legs, and to the pleopods.

The blood from the capillaries of these arteries escapes into the ***blood sinuses (haemocoele)***, whence it finally collects in a pair of large interconnected ***sternal*** or ***ventral*** sinuses in the cephalothorax. Six pairs of ***afferent branchial channels*** convey the blood from the sternal channel to the gills for oxygenation. The oxygenated blood passes through six pairs of ***efferent branchial channels*** to the pericardial chamber. The course of circulation is represented diagrammatically in fig. 225.

Respiratory system.—The respiratory organs consist of three pairs of ***epipodites*** and the eight pairs of ***branchiae*** or gills, enclosed in the ***branchial chamber***. The ***branchiostegite*** or the lateral

part of the carapace forms the branchial chamber that is open below, in front and behind. The branchiostegite is lined on the inside by a thin membrane, enclosing a blood lacuna and thus forms an important respiratory surface. A gill consists of two rows of diverging flat ***gill plates*** arranged on a long ***base,*** like the leaves of a book. Three longitudinal blood channels run through the base two lateral and the third median. The lateral channels are connected together by numerous transverse channels. Marginal channels from the lateral penetrate into each gill plate and open into the median channel. The scaphognathite constantly moves back and forth and thus sets up a current of water into the branchial chamber. The water enters the branchial chamber from behind, washes over the gill plates and goes out anteriorly.

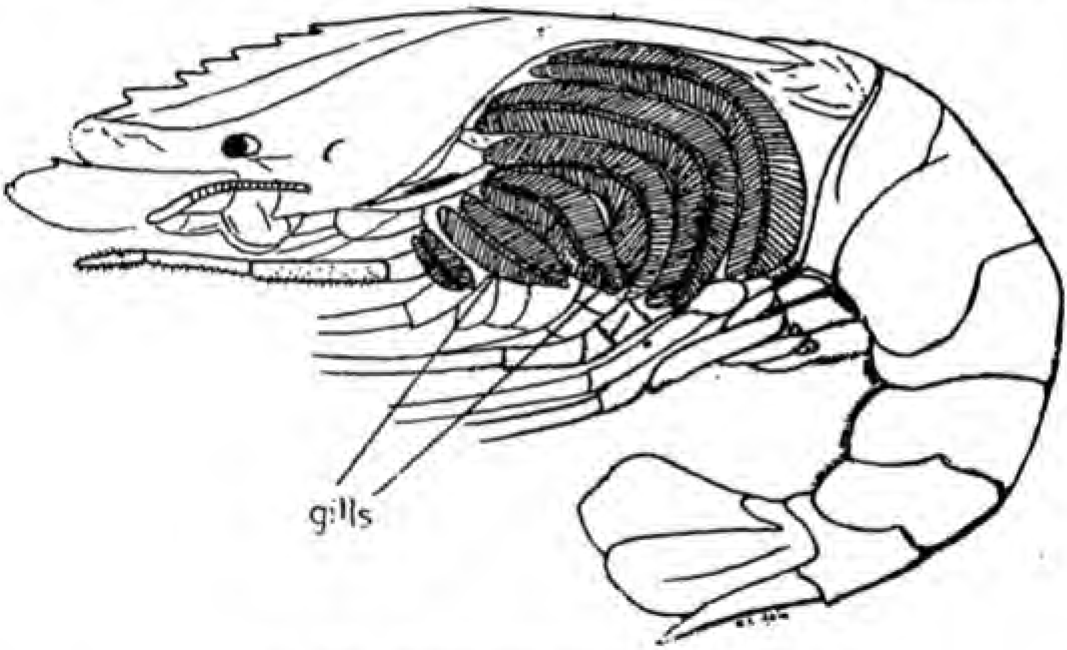


FIG. 226. Respiratory system of the prawn.

The gills are of three types according to their location : 1. ***podobranch*** if attached to the coxopodite of an appendage ; 2. ***arthrobranch*** if attached to the membrane between the body and the appendage ; and 3. ***pleurobranch*** when on the lateral wall of the body. There are a pair of podobranchs on the second maxillipede, two pairs of arthrobranchs on the third maxillipede and five pairs of pleurobranchs.

Excretory system.—A pair of ***green-glands*** in the coxopodite of the antennae constitute the excretory organs of the prawn. The green-gland includes the end sac, labyrinth and bladder. The bladder continues behind as the ***lateral ducts*** to the ***renal sac*** above the

cardiac stomach in the cephalothorax. The ureters from the bladder open to the outside on the inner side of the coxopodite of the antenna.

Reproductive system.—The sexes are separate. The female is relatively small and has the second chelate legs relatively long. The genital organs of the female include a pair of ovaries and oviducts. The ovaries lie between the hepatopancreas and pericardium and become large during the breeding season. The male organs comprise the paired testes, vasa deferentia and seminal vesicle. The testes correspond to the ovaries in position.

Nervous system.—The nervous system includes 1. a paired ***supra-oesophageal ganglion*** connected by 2. paired ***circumoesophageal commisures*** to the large ventral ***thoracic ganglionic*** mass, that gives off 3. the ***ventral nerve cord*** behind. The thoracic ganglionic mass represents eleven pairs of fused ganglia. The ventral nerve cord bears six pairs of ganglia in the abdomen.

The brain gives off paired 1. optic nerves to the retina of the eye, 2. ophthalmic nerves to the muscles of the stalk of the eye, 3. antennulary nerves and 4. antennary nerves. From the thoracic ganglion arise eleven pairs of nerves supplying the mandibles, maxillulae, maxillae, maxillipedes and legs.

The sense organs comprise 1. the eyes, 2. statocysts, 3. olfactory and 4. tactile organs.

The eyes are situated on a two-jointed stalk that can be moved up and down or back and forth. Each eye is compound : it is composed of numerous ***ommatidia*** or simple eyes corresponding to the numerous ***facets*** on the surface.* The statocysts are globose sacs in the basal segment of the antennules. The statocyst opens to the outside by a small aperture covered by an integumental fold. It is filled with minute sand granules and is lined by sensory setae. The statocyst is the organ of orientation that serves for perceiving changes in the direction of gravitation. With changes of position of the body, the sand granules press against the sensory hairs, which are connected by nerve fibres to the brain. The antennae are the chief tactile organs. The smaller feeler of the antennule is the olfactory organ.

Behaviour.—The prawn lives in burrows in streams and rivers and it resists being dragged out of its burrow. It uses the chelate legs in defence. It can walk on the bottom in any direction : forward, backward or

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* For a fuller description of the compound eye and its mode of action see under Cockroach.

sideways. It also swims backward by darting movements. It loves contact and concealment. If a leg or other appendage is severely injured, the prawn performs a surgical operation on itself and amputates the injured leg; a new leg then grows in place of the one lost.

RESUMÉ

I. Arthropoda

1. The Arthropoda are the dominant phyla.

2. The Arthropodan plan of body is an elaboration and specialization of the annelidan plan. Each body segment has typically a pair of jointed appendages. There is an exoskeleton.

3. The Arthropoda comprise the Crustacea, Pycnogonida, Xiphosura, Arachnoidea, Diplopoda, Pauropoda, Symphyla, Chilopoda, Onycophora, Tardigrada, Pentastomida and Insecta.

II. The Prawn

4. The common prawn inhabits rivers. It is mostly nocturnal in its habits.

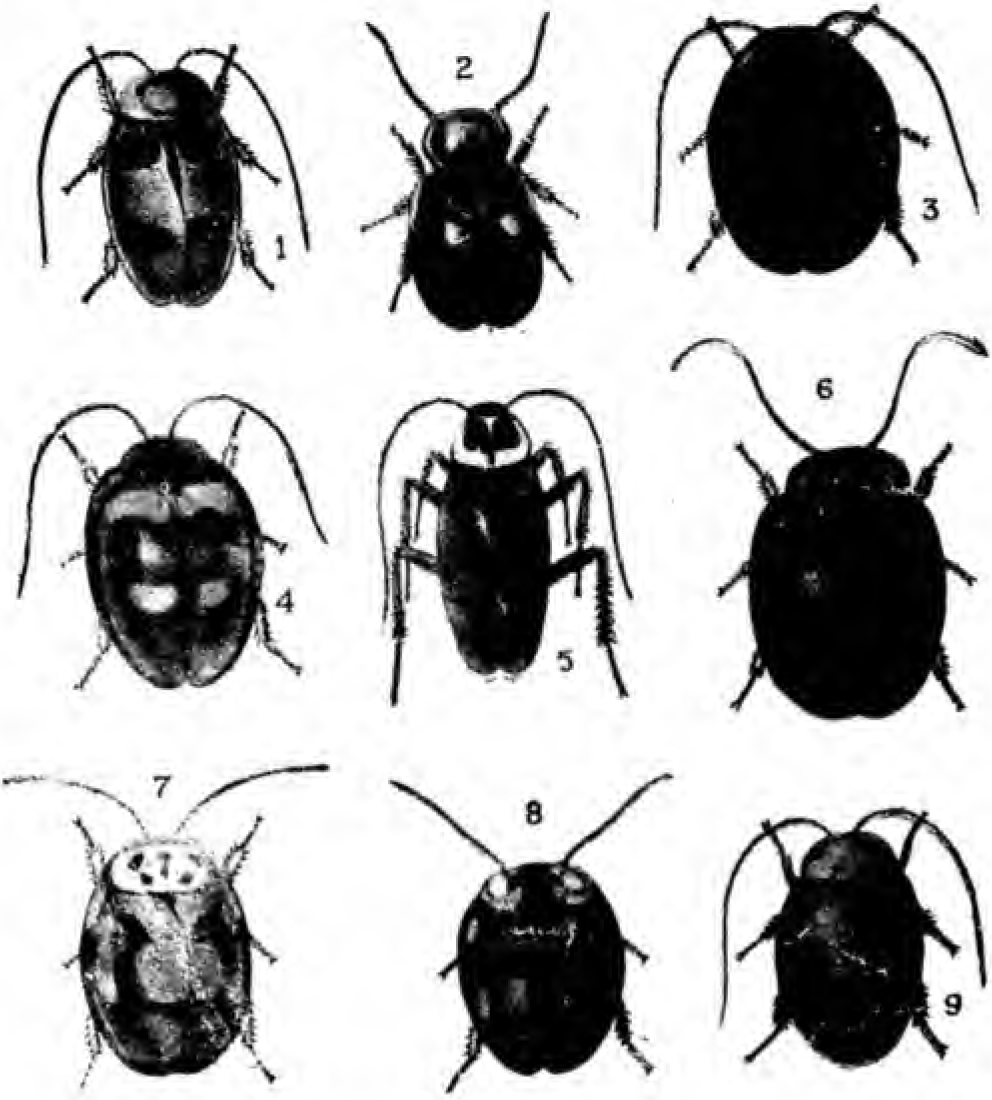
5. The body consists of a cephalothorax and abdomen and bears several paired biramous appendages that serve as feelers, jaws, feet, gills, etc.

6. The hepatopancreatic glands combine the functions of the liver, pancreas and intestine. They not only help digestion but also perform the absorption of food.

7. The blood contains haemocyanin as the respiratory pigment. The circulatory system is of the lacunar type.

8. The nervous system is essentially as in the earthworm but several of the ganglia are fused together. The organs of special sense include the compound eyes, composed of numerous ommatidia and the statocysts.

PLATE II



Cockroaches are not ugly creatures as popularly conceived. Some of them are brightly coloured objects of beauty. Here are some Old World cockroaches: 1. *Prosoplecta trifaria* (female), 2. *P. rufa*, 3. *P. coelophoroides*, 4. *P. quadriplagiata*, 5. *Periplaneta americana* the common cockroach, 6. *Prosoplecta semperi*, 7. *P. gutticollis*, 8. *P. mimas* and 9. *P. trifaria* (male). (*All except the 5th after Shelford Proc. zool. Soc. London*, 1912).

CHAPTER XIV

INSECTA—THE COCKROACH

The INSECTS are the dominant animals at the present time on the earth. Over three quarter of a million species of insects have already been named and described! It is estimated that there are actually ten times more yet waiting to be discovered. Descriptions of insects fill libraries. Thousands of scientists are engaged all over the world in the study of ***entomology*** or the science of insects.

Not only do insects far exceed in number of species and of individuals all other animals combined, but they are also the most widely distributed, most powerful, most useful, most dangerous and most everything. If any animal has made a most brilliant success of life, it is the insect. They were one of the first to invade the dry land and the air in the great past and thus had all the advantages of an earlier start of nearly 250 million years over man. This is not the only reason for their success. Their organization, structure, food, habits and development make them the best fitted for life. Insects are found everywhere: in the field, in tanks, ponds, streams, over high mountains, in deep wells, deserts, in the house, store, in the laboratory, museum, libraries, on or in our bodies and of our domesticated animals and in fact in every conceivable place. Their food includes all that can be eaten: not only such things like leaves, wood, flesh, grains, fruits, etc., but also clothes, paper, wool, rubber and even metal lead! Their strength and powers of endurance are truly astounding. A *Lucanus* (stag-horn beetle) can, for example, drag ninety times its own weight for a distance thirty times its own length for twenty-five minutes. A flea has legs hardly one-twentieth of an inch long but it can jump a horizontal distance of thirteen inches and a height of about eight inches. If a man were to do a similar feat, he must take a long jump of about seven hundred feet and a high jump of about four hundred and fifty feet! The powers of reproduction in the insects are also unimaginably enormous. A pair of flies, for example, would reproduce in six months to the enormous number of 191 010 000 000 000 000 flies! As each fly occupies one-eighth of a cubic inch of space, these flies would cover the entire earth to a height of forty-seven feet if spread uniformly all over. Their senses are again much more acute than those of other animals. Insects can see and

hear when man cannot. It is therefore no wonder that insects are the most successful of all animals.

Insects hunted or gathered the harvest long before man was born. They built roads, bridges, houses, prefabricated log wood cabins, and sky-scrapers when there were no human engineers. They raised huge armies and used poison gas and bacterial weapons while Europe had not yet been born. They domesticated animals, kept playful pets and had slaves too. Lastly, insects have even evolved a cent per cent secular and socialistic government, from which we are even today very far off !

Insects are Arthropods typically with the body segments differentiated into head, thorax and abdomen. They have only three pairs of legs, which are confined to the thorax. Many of them have one or two pairs of wings on the thorax. The appendages on the head are modified as mouthparts for grasping, or chewing food or for piercing or puncturing skins and stucking liquids. They have both simple and compound eyes. Their body is the most perfectly air-conditioned system; respiration is effected by the air reaching every minute part of the body in a system of branched tubes called ***trachea***. Most insects are terrestrial. Some are aquatic and others are parasitic on various animals including other insects.

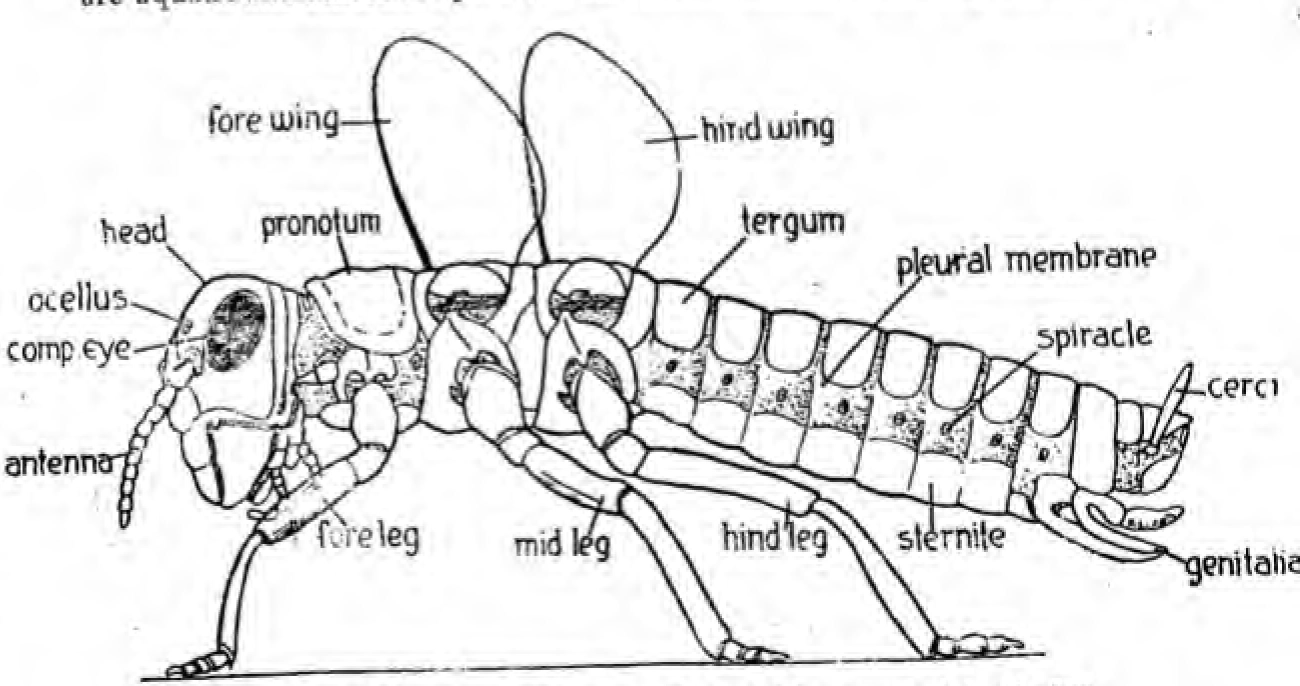


Fig. 227. A generalized insect. External features in lateral view.

Insects differ from the other Arthropods in 1. division of the body into head, thorax and abdomen, 2. three pairs of legs and 3. wings. These characters at once separate them from the scorpions, spiders, millipedes, centipedes, mites, ticks, etc., which are not insects.

Characters.—

1. Body with head, thorax and abdomen distinct.

2. Head with one pair of antennae and mouthparts for biting and chewing, piercing and sucking, lapping, siphoning, etc.

3. Thorax with three pairs of walking legs and usually two pairs and sometimes one pair of wings, rarely wings reduced or absent.

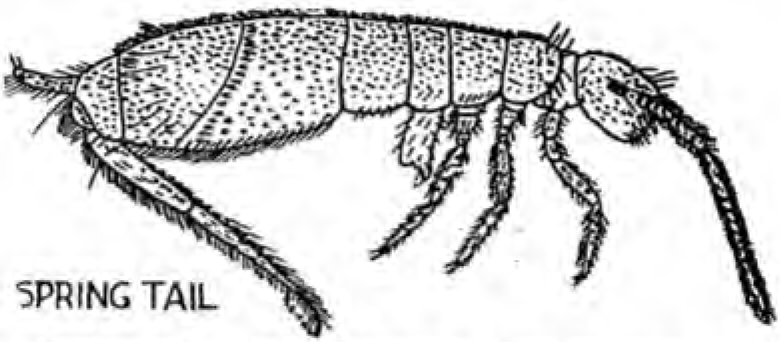


FIG. 228. Class insecta. Order Collembola. The springtail is a minute, soft-bodied insect that occurs in damp places. The springing tail that is engaged in a stump-like ventral appendage on the base of abdomen is suddenly released and the insect shoots forward into the air.

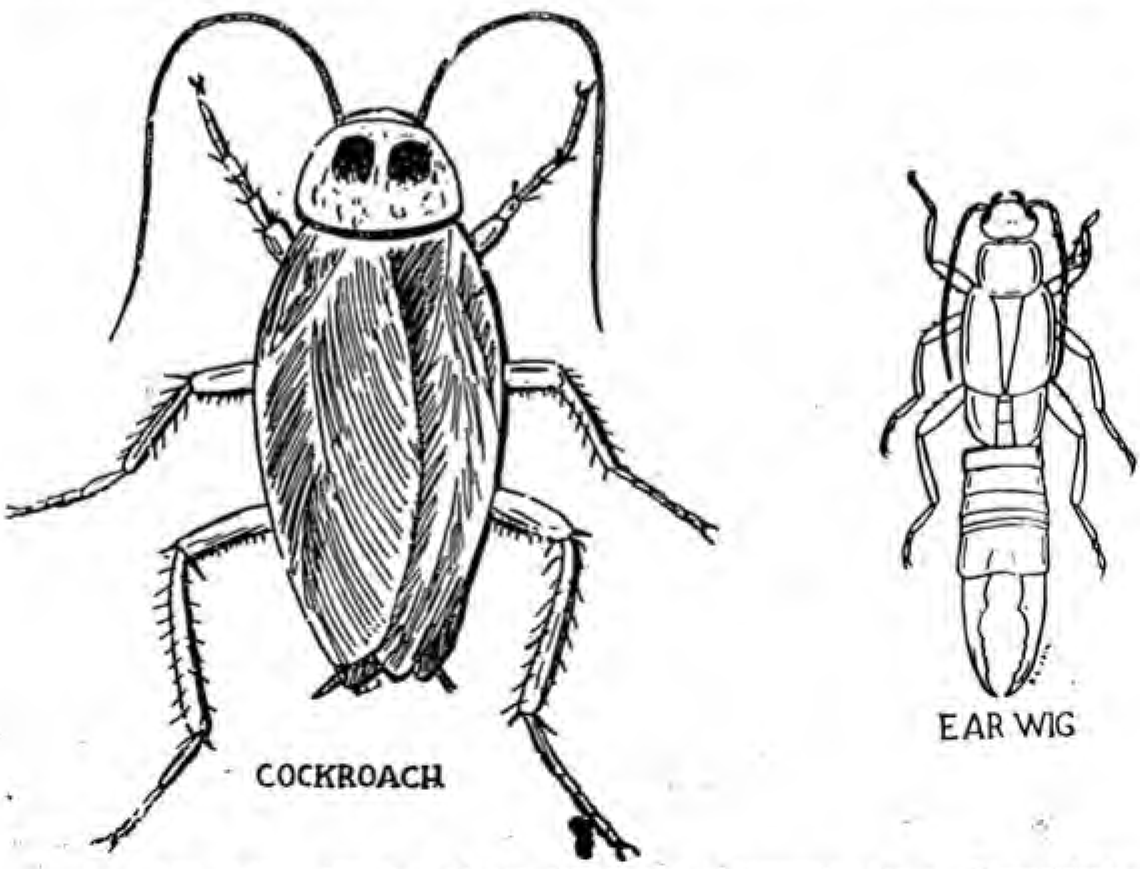


FIG. 229. Class Insecta. Order Blattaria: Cockroach. Order Dermaptera: Earwig.

4. Salivary glands often present.
5. Heart a tube, without arteries or veins.
6. Respiration by tracheal tubes.
7. Excretion by Malpighian tubules.
8. Nervous system of the annelidan type.
9. Sense organs include simple and compound eyes, olfactory, tactile and auditory organs.
10. Sexes always separate
11. Development often with metamorphosis.
12. Size: some are smaller than large Protozoa, while others are larger than small Vertebrates. Some egg parasites are less than 0·25 mm. long and the longest measure 260 mm. Some fossil insects measured 700 mm.

Classification.—The living insects are grouped among 34 orders, of which the following are the more important:

Subclass I. APTERYGOTA. Primarily wingless insects without metamorphosis.

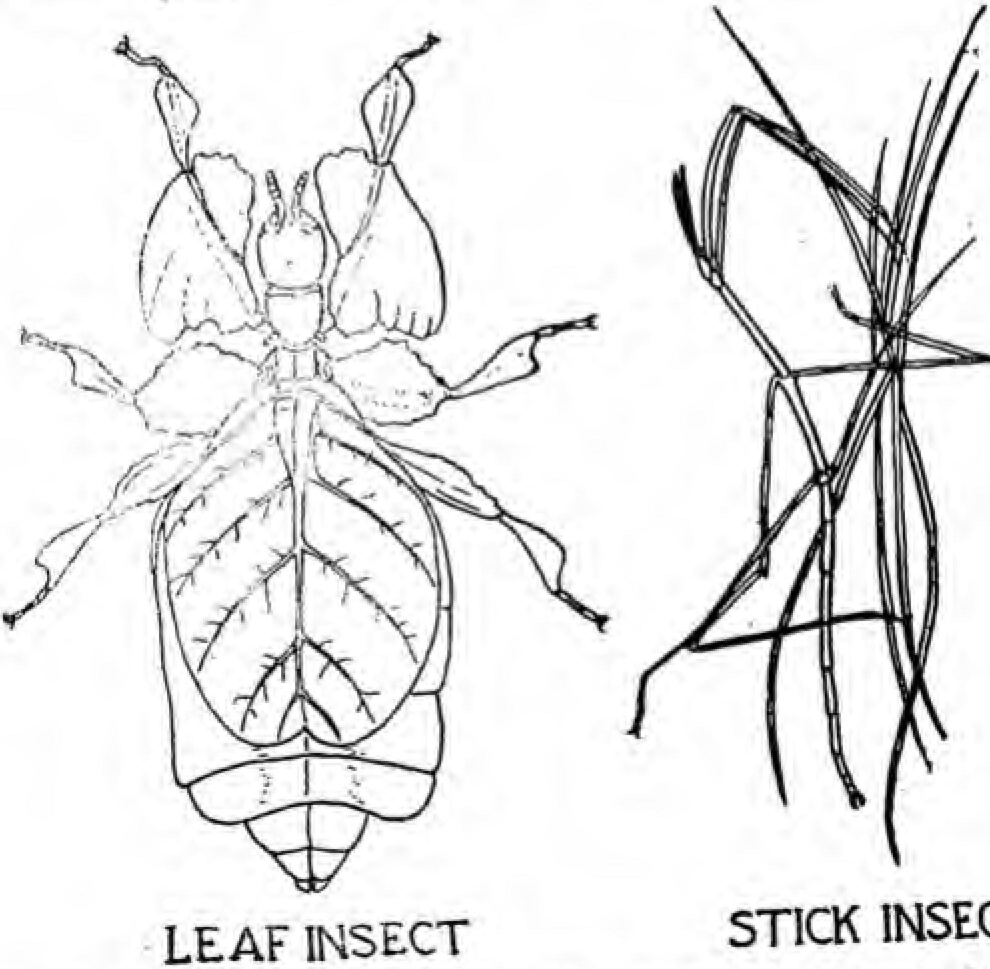


FIG. 230. Class Insecta. Order Phasmida: *Phyllium bioculatum*, the leaf insect has flattened and green body and expanded green legs and has a surprising resemblance to a leaf. *Carausius* the stick insect has slender body that matches in colour and appearance with sticks.

The common salivary duct opens on the hypopharynx. The true mouth is high up above the mandibles.

Thorax.—The thorax includes the large ***prothroax*** and the relatively small ***mesothorax*** and ***metathorax***. Each of the segments of the thorax bears a pair of legs; there are thus three pairs of legs. Each leg is composed of a short, flat ***coxa***, a small ***trochanter***, an elongated

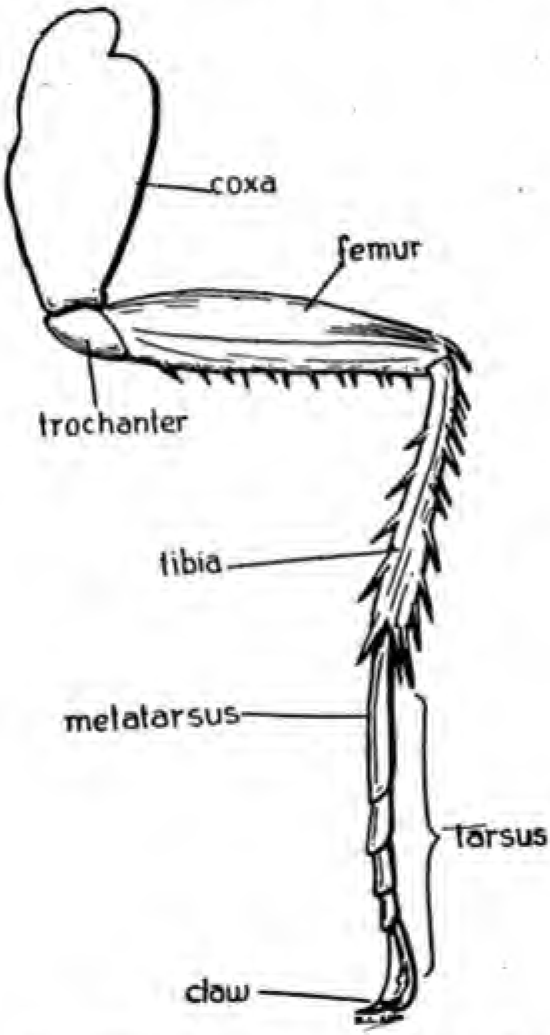


FIG. 238. *Periplaneta americana.* Leg.

and stout ***femur***, a long slender ***tibia*** and a five-jointed ***tarsus*** ending in a pair of curved sharp claws. All the legs are used in walking, running or climbing. The forelegs extend forward, seize the ground and drag the body. The midlegs support and steady the body. The hindlegs push the body forward.

The prothroax has no wings. The mesothorax bears a pair of wings dorsally. These wings are elliptic oval or oval horny structures called ***tegmina*** and are not used in flight. They serve to cover the wings of the metathroax. These latter are membranous structures, strengthened by ***veins*** or ***nervures*** and folded lengthwise under the tegmina when not in use. The wing veins are of constant pattern in each insect and form the basis of classification.

Abdomen.—The abdomen is broadly attached to the thorax and bears no legs. There are ten complete segments excluding the anal one, but several of them are modified and tucked under others. In the female, the abdomen is broader than in the male. The eighth and ninth segments are very narrow. The tenth segment bears a pair of small, short lateral, many-jointed ***cerci***. The genital opening is located between the ninth and tenth segments in the male and in the eighth segment in the female. The ninth segment bears ventrally a pair of short unjointed ***styles*** in the male.

Skeleton.—The sclerites formed by thickening of the integument 1. give a definite shape to the body, 2. support and protect the internal organs, 3. provide attachment to muscles and 4. form the frame-work of the body. They therefore constitute the skeleton of the cockroach. The skeletal system of the cockroach differs however essentially from that of the frog : the skeleton lies on the surface of the body and the muscles which are attached to it do not surround it as in the case of the bones of the frog, but the muscles are enclosed by the skeleton (Fig. 209). It is thus an ***external armour*** or ***exoskeleton***. The exoskeleton is largely composed of ***chitin***, overlying the hypodermis. Chitin is a non-cellular nitrogenous polysacharide $(C_{32}H_{54}N_4O_{21})\,x$, insoluble in water, alkalies, dilute acids and in the digestive secretions of most animals. It thus resists the evaporation of water from the tissues and forms an effective armour plate for the soft parts. To permit movements of the body, it is flexible between the body segments and in the joints of appendages The exoskeleton is in effect a fixed external armour that severely limits the size of the animal. Growth would be impossible but at intervals there is a shedding off of the old skeleton by a process called ***moulting*** or ***ecdysis***. Prior to an ecdysis a new soft exoskeleton forms beneath the old one, which now becomes loosened, splits dorsally and the animal creeps out. It now expands rapidly before the new exoskeleton gets hardened. The last ecdysis takes place just when the insect becomes an adult. The exoskeleton has important advantages over the hard bony endoskeleton ;

it is stronger and at the same time lighter. It combines strength, rigidity, lightness, flexibility, mobility, elasticity and protection. It is thus superior to such armours as the heavy shells of snails.

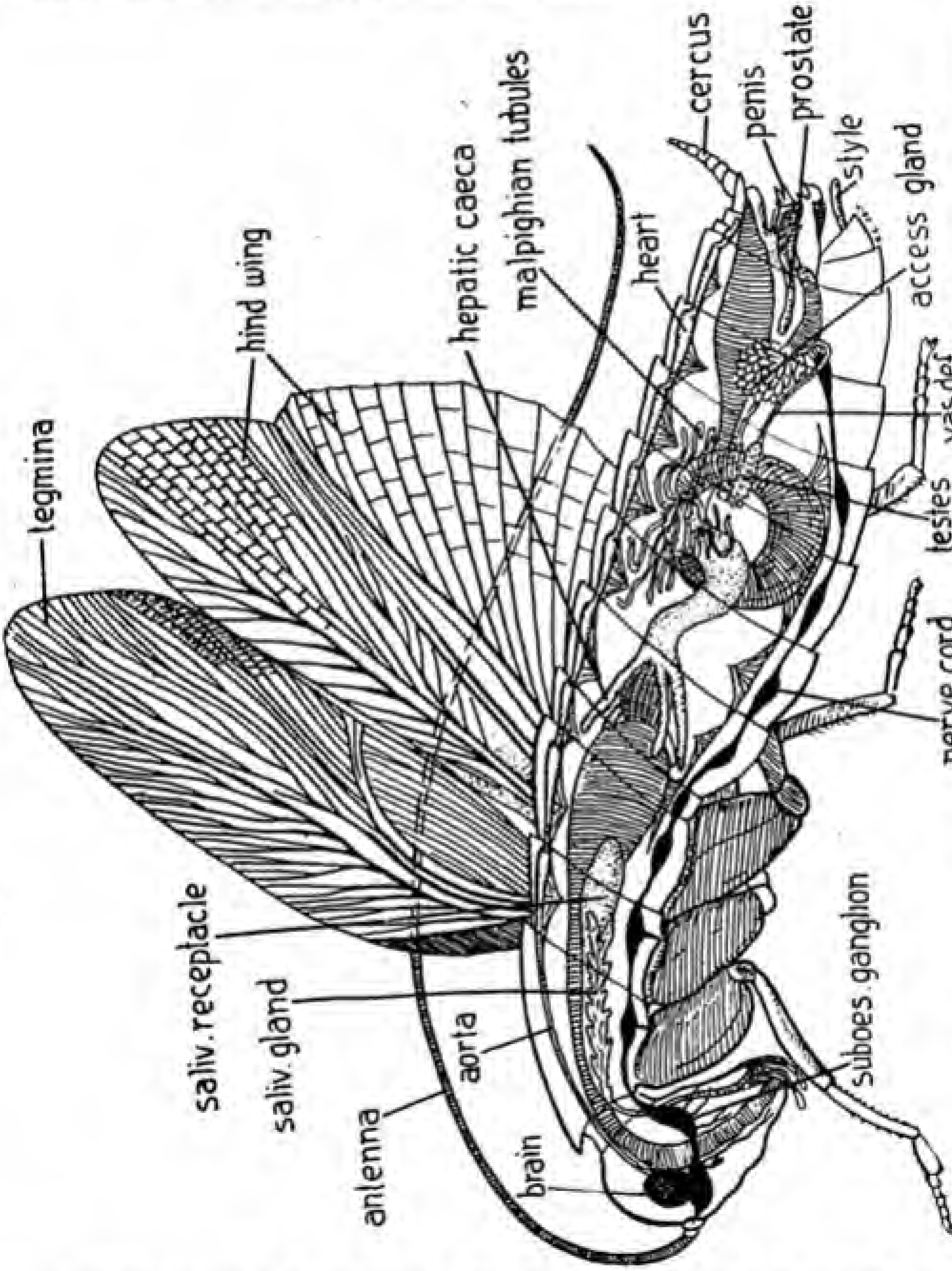


FIG. 239. *Periplaneta americana.* Diagram of the organization of the adult cockroach (male) lateral view from right side, showing the body segmentation, the alimentary, circulatory, nervous and reproductive systems. (*From* Hermann Weber: *Grundriss der Insektenkunde, Gustav Fischer, Jena*).

The exoskeleton of the head (Fig. 236) comprises 1. a pair of ***epicranial plates***, joined by a median ***epicranial suture*** and covering the top, the greater part of the back and sides of the head, 2. a ***clypeus*** in front to which the labrum is hinged below and 3. ***gena*** which forms the

cheek or the part behind and below the eyes. The foraman magnum is bordered in the cavity of the head by a strong rim, which gives off anterior arms. The rim and its arms constitute the ***tentorium*** or the internal or endoskeleton of the head.

The skeletal elements of each segment of the thorax and abdomen comprise a dorsal sclerite called ***tergum*** or ***notum*** and a ventral sclerite or ***sternite***. The pronotum or the terga of the prothroax is the largest of the thoracic tergites. It is broadly triangular, with the broad base directed behind. It projects on all sides and also conceals the head. The sternites of the thorax are small. The tergites and the sternites of the abdomen are large, transverse, arched plates; the tergites project somewhat laterally beyond the sternites. The hind margins of the tergum and sternum of one segment slightly overlap the front margins of those of the next.

Musculature.--Nearly all the muscles, both voluntary and involuntary, are striated muscles. The head contains a complex set of muscles that work the antennae and the mouthparts. The muscles that move the mandibles are the most powerful of these. The muscles of the antennae and the mouthparts have their origin and insertion within the head itself and thus comprise the ***intrinsic head muscles***. Some of the muscles of the thorax move the head and are inserted in the head; these are the ***extrinsic head muscles***. The muscles of the thorax are very complex and very powerful. Some of them are longitudinal and others dorsoventral. They serve to move the wings and legs. They are essentially the chief locomotor muscles of the cockroach. Besides, each leg contains a set of muscles that move the various segments of the leg. The abdomen contains longitudinal, oblique and other muscles.

Digestive system. The digestive system of the cockroach includes the 1. mouthparts and 2. the alimentary canal and its associated glands. The mouthparts have already been described.

Alimentary canal.—The labrum in front and the labium behind enclose a ***pre-oral chamber***, in which the mandibles, the first maxillae and the hypopharynx are contained. The external opening of the chamber is not really the true mouth: it is the ***functional mouth***. The ***true mouth*** is located higher up the chamber at the level of the base of the mandibles. The pre-oral chamber is divided into an anterior and a posterior part by the median unpaired hypopharynx. The anterior part contains the mandibles and the maxillae and is thus called the ***cibarium*** or chewing cavity. Into the posterior part, the salivary ducts open and is therefore the ***salivarium*** or the salivary chamber.

The alimentary canal (Fig. 240) of the cockroach is always longer than the body of the cockroach and is therefore looped or coiled. It begins in the true mouth and ends in the anus. It consists of three parts : 1. ***stomodaeum*** or foregut, 2. ***mesenteron*** or midgut and 3. ***proctodaeum*** or hindgut. The fore and the hindguts are extensive and are really the external integument that is deeply invaginated and are therefore ectodermal in origin.

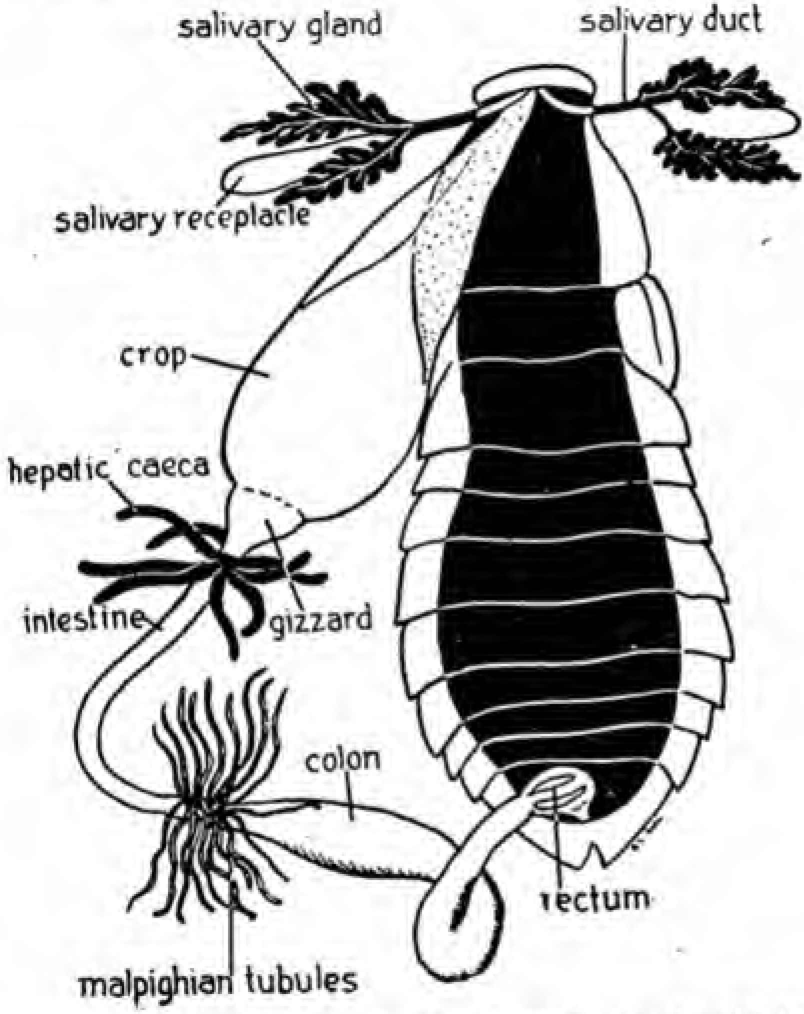


FIG. 240. *Periplaneta americana.* The alimentary system in dorsal view.

They are lined by a chitinous ***intima*** (Fig. 241). The short midgut is formed out of the archenteron of the embryo and is therefore endodermal in origin ; it lacks the intima. The foregut is differentiated into the following regions : 1. ***pharynx***, 2. ***oesophagus***, 3. ***crop*** and 4. ***proventriculus*** or ***gizzard***. The midgut is the short small stomach. The large intestine and the rectum comprise the hindgut. The mouth opens into a short buccal cavity, which immediately continues as the pharynx. The pharynx passes

through the nerve ring. A number of muscles arising from the inner surface of the head capsule and inserted on the pharynx, serve to dilate the pharynx for the passage of food (Fig. 241). The pharynx passes gradually

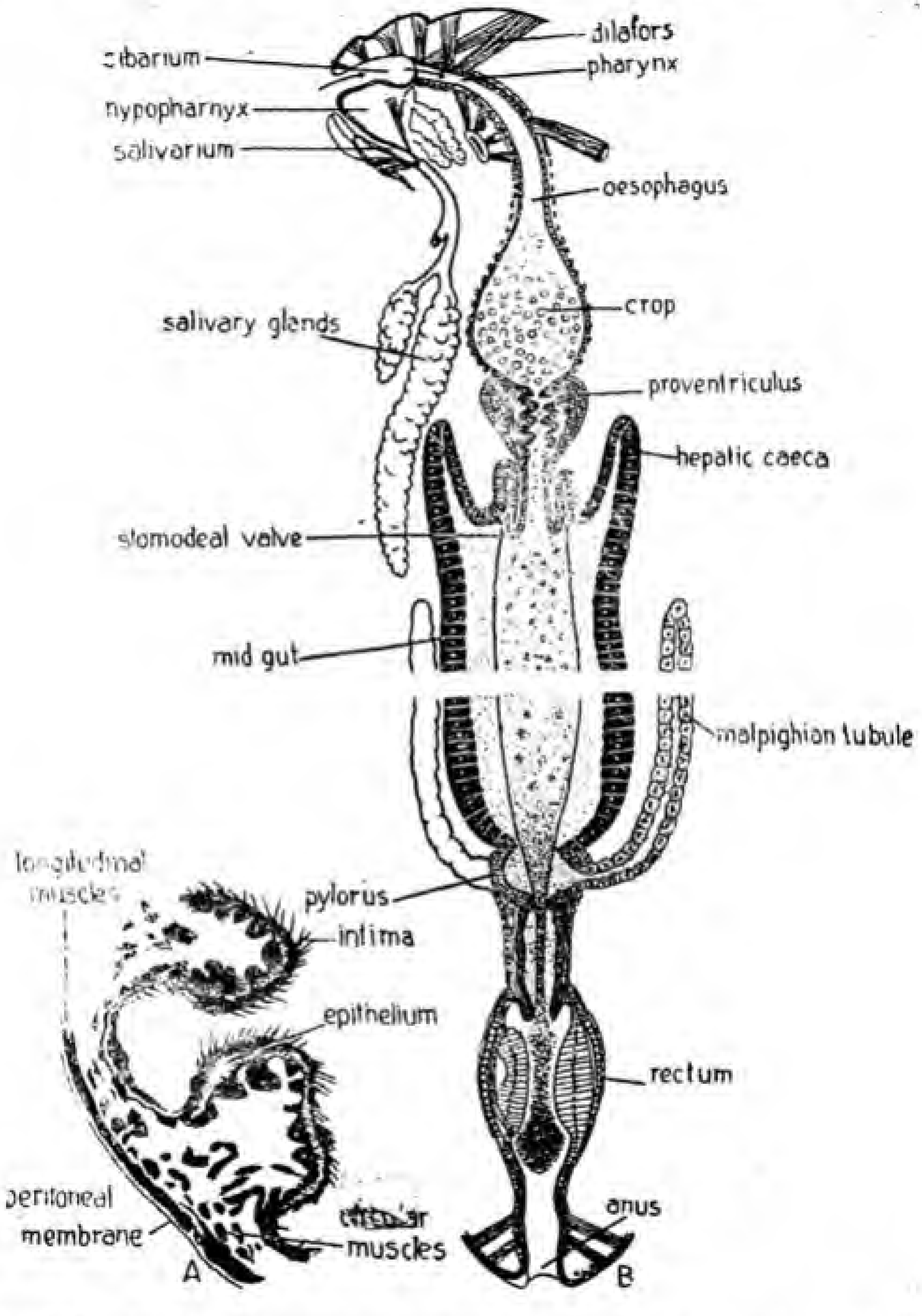


FIG. 241. A. Part of transverse section of foregut to show the intima. (The circular muscles lie superficially and are erroneously labelled as longitudinal; the longitudinal are wrongly labelled as circular). B. Diagram of the fundamental plan of alimentary canal of a generalized insect in median longitudinal section. (*From Hermann Weber : Grundriss der Insektenkunde, Gustav Fischer, Jena*).

into the compressed oesophagus, that leaves the head through the foramen magnum and enters the thorax.

In the thorax the oesophagus is enlarged into a spacious, long and thin-walled ***crop***, which extends backward into the first part of the abdomen. The wall of the oesophagus and crop is thrown into numerous longitudinal folds that project into the lumen (Fig. 241). The outer surface is covered by a net-work of tracheal tubes. The wall of the crop is composed of circular and longitudinal muscular coats, epithelial layer and the intima. The muscular coat comprises only striated fibres, unlike in the case of the oesophagus of the frog. The epithelial layer secretes the intima, which bears stiff chitinous hairs or bristles (Fig. 241). These bristles are directed backward. The crop is an organ of storage of food. Cockroaches that are fed on oil and sugar, store these up in the crop for nearly two months, before they are finally digested and absorbed.

The ***proventriculus*** (often erroneously called gizzard), the last part of the stomodaeum, is a short, bluntly cone-shapped, thick-walled structure. It is the most highly specialized part of the digestive canal. The muscular coat of its wall is of considerable thickness and includes many layers of circular muscles. The inner lining projects into the lumen as six longitudinal folds, that are densely sclerotized anteriorly and form an armature of six plates. Each of these plates is produced into a sharp tooth-like process pointed backward. In the posterior part the folds are again thickened into cushion-like stuctures and covered by stiff bristles, which are also directed backward. The teeth-like plates can be approximated together by muscles and constitute an efficient grinding and straining apparatus. The posterior part of the inner lining of the proventriculus projects like a narrow tube into the cavity of the mid gut as the ***stomodeal valve*** (Fig. 241).

The midgut is a short tube lined by columnar epithelium. It is essentially the stomach of the cockroach and is also called the ***ventriculus***. There is no chitinous intima in the wall of the ventriculus. The muscular coat also differs from that of the stomodaeum : the longitudinal muscles are external and the circular muscles are internal. Eight short finger-shaped ***hepatic caeca*** are attached to the anterior end of the ventriculus. Each of these caeca is hollow and closed at the free end, but open into the midgut cavity at the attached end. They secrete a digestive fluid into the ventriculus.

The proctodaeum follows directly behind the ventriculus. It is essentially a tube that extends from the stomach to the anus. Just anterior

to the commencement of the proctodaeum are the fine ***malpighian tubules*** attached to the gut. The proctodaeum is differentiated into an anterior short narrow ***ilium*** or ***intestine***, a posterior ***colon*** or large intestine and a short terminal ***rectum***, with longitudinally folded walls. The proctodaeum is lined by intima and the inner lining is thrown into six longitudinal folds in the rectum.

A pair of large grape-bunch-shaped ***salivary glands*** and a pair of large ***salivary receptacles*** are found in the thorax. The ducts of the receptacles join to form the common ***salivary meatus*** into which the common ducts of the salivary glands open. The salivary meatus opens posteriorly on the hypopharynx in the pre-oral chamber.

Circulatory system.—(Fig. 242). The circulatory system is of the lacunar type, i.e. it is not closed, there being no capillaries or veins. The heart is a long slender tube that lies in the median longitudinal line of the abdomen and thorax beneath the dorsal body wall in a shallow pericardial cavity, formed by a thin diaphragm. The heart consists of thirteen chambers following one in front of the other. Each chamber has a pair of minute lateral apertures or ***ostia***, guarded by valves. Anteriorly the heart continues as a short ***aorta***, which opens into the haemocoelomic space in the head. The heart pulsates from behind forwards and the blood enters it through the ostia from the pericardical chamber.

The blood consists of ***plasma*** or ***haemolymph*** and ***haemocytes*** or colourless blood corpuscles. There is no respiratory pigment in the blood to carry the oxygen. The blood serves as the distributing and collecting medium for food and wastes, acts as a food reservoir, expands wings, aids moulting by pressure, kills bacteria, etc.

Respiratory system.—The cockroach has a most efficient respiratory system, which makes up for the poorly developed circulatory system. The blood is not oxygenated in lungs as in the frog or in gills as in the prawn, and not carried to every minute part of the body. Instead the air itself reaches every ultimate cell directly in a system of branched tubes called ***trachea***. The trachea opens to the atmosphere by ***spiracles*** on the surface of the body. In the frog the blood goes to the lungs for oxygen, but in the cockroach, the oxygen itself goes directly wherever it is needed. The cockroach has thus a well developed ***air-circulatory*** system. The respiratory activity of the cockroach is thus much more intensive than that of the frog. More energy is thus liberated. Cockroaches and

other insects are therefore much more active and perform much greater feats of strength than all other animals.

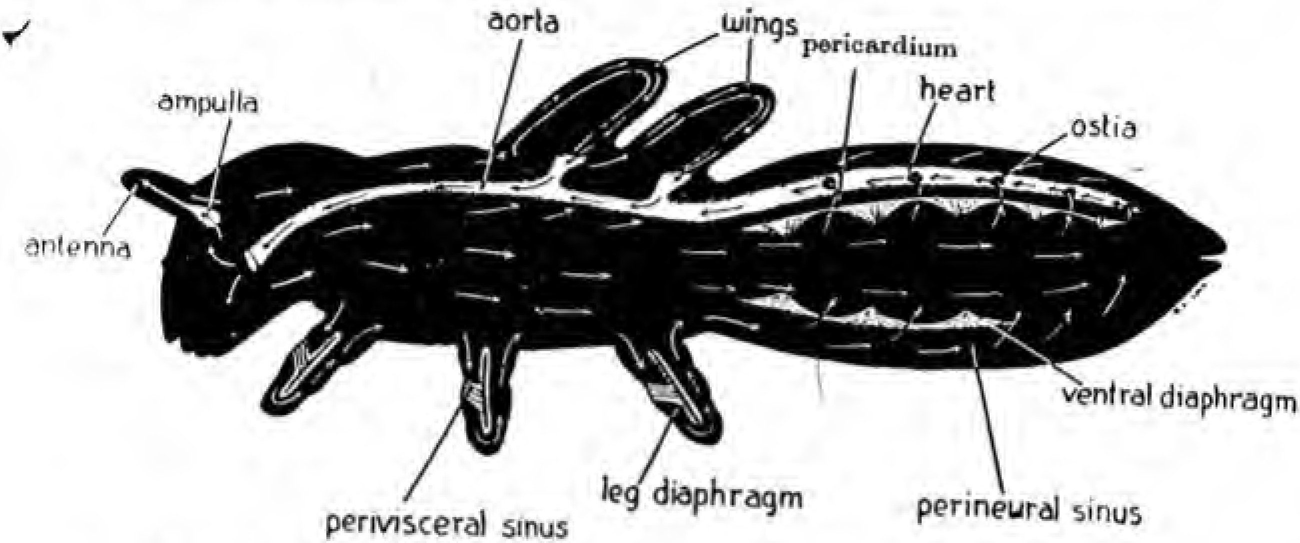


FIG. 242. The circulatory system of an adult insect. The direction of the blood flow is indicated by arrows. (*Modified from Hermann Weber : Grundriss der Insektenkunde, Gustav Fischer, Jena*).

The tracheal system begins in the ***spiracles***. There are ten pairs of spiracular openings or ***stigmata*** in the cockroach : the first pair lies in the mesothorax, the second in the metathorax, and one pair in each of the first eight abdominal segments. The prothorax and the head lack spiracles. The spiracles can be closed or opened by the cockroach by means of a special closing mechanism Each spiracle opens into a short ***spiracular trunk***, which gives off a ***dorsal trachea, ventral trachea*** and a ***longitudinal trachea*** (Fig. 243). The longitudinal tracheae of the spiracles join together to form a continuous lateral longitudinal tracheal trunk. The dorsal and ventral branches ramify repeatedly, becoming finer and finer, and penetrate all parts of the body. The mesothoracic spiracle supplies four large tracheal trunks to the head.

The trachea is essentially an infolding of the integument. It is lined by chitinous intima in the form of spiral thickenings. The finer branches called ***tracheoles*** lack the spiral thickenings.

The circulation of air in the tracheal system is ensured by the throbbing movements or alternate contraction and expansion of the abdominal wall. The spiracle is opened and the expansion of the abdomen forces the air through the spiracles into the trachea. The spiracle is now closed and the abdomen contracts, compressing the air, which is

thus forced into the finest recesses of the tracheoles. The spiracles open and the abodomen expands. More air is sucked into the tracheae and again forced into the finer tracheoles. Further contraction, with the spiracles open, forces the de-oxygenated air out. The respiratory movements of the abdomen are reflex actions. The greater the muscular activity of an insect, the more vigorous is the pumping in-and-out of the air. Considerable quantities of oxygen are often stored within the tracheal tubes. Cockroaches have astonishing powers of recovering after being exposed to an atmosphere of CO_2 or inert gases.

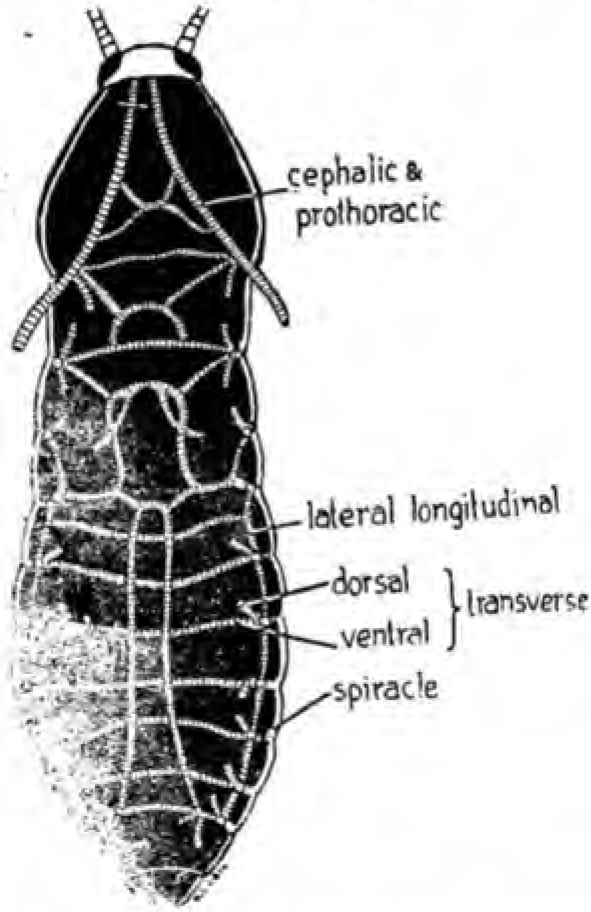


Fig. [illegible]. *Periplaneta americana*. The tracheal system in dorsal view.

Excretory system.—The malpighian tubules comprise the excretory organs of the cockroach. There are six bundles of these tubules. Each bundle comprises about ten thread-like tubules. The tubules are closed at their free end but open into the hindgut proximally. The inner lining of the tubules consists of glandular cells and the lumen is often filled up by crystals of uric acid. The tubules separate the urates from the blood surrounding them. The crystals are emptied into intestine to be thrown out with faeces.

Nervous system and sense organs.—The nervous system of the cockroach is constructed on the same fundamental plan as in Annelida and Crustacea. There is however a greater degree of specialization. It comprises the brain, ganglia and ventral nerve cords. Several of the ganglia are fused together, so that some of them are larger that the others.

The brain or the ***supra-oesophageal*** ganglion lies in the head. It is very small when compared with the size of the head. It consists of a bilobed mass lying dorsad and somewhat in front of the oesophagus. It is really a ***syncerebrum*** or a compound brain composed of three fused ganglionic pairs: ***protocerebrum, deutocerebrum*** (pronounced *daitocerebrum*) and ***tritocerebrum*** (Figs. 244, 245).

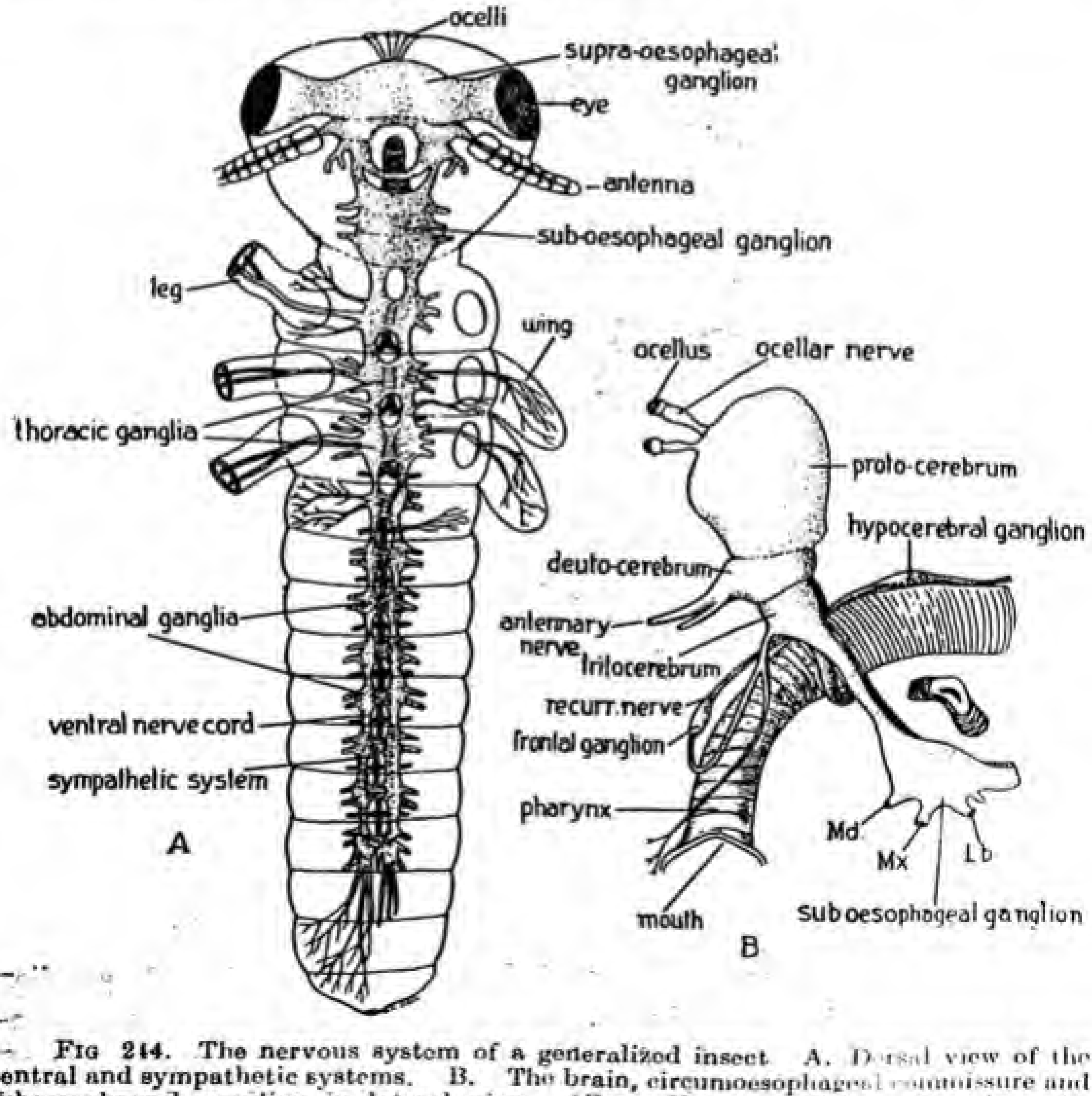


FIG 244. The nervous system of a generalized insect. A. Dorsal view of the central and sympathetic systems. B. The brain, circumoesophageal commissure and suboesophageal ganglion in lateral view. (*From Hermann Weber : Grundriss der Insektenkunde, Gustav Fischer, Jena*).

The protocerebrum gives off laterally a pair of short, very stout optic nerves going to the two compound eyes. The deutocerebrum gives off nerves to the antennae. The labrum is innervated from the tritocerebrum.

The tritocerebrum also gives off a pair of stout ***circumoesophageal commissures,*** which encircle the oesophagus like a ring, pass downward and backward to the ***suboesophageal ganglion.*** The suboesophageal ganglion lies below the oesophagus and in front of the mentum (Fig 244). This ganglion is also a compound mass and is composed of three fused ganglionic pairs. It gives off the paired ***mandibular, maxillary*** and ***labial*** nerves.

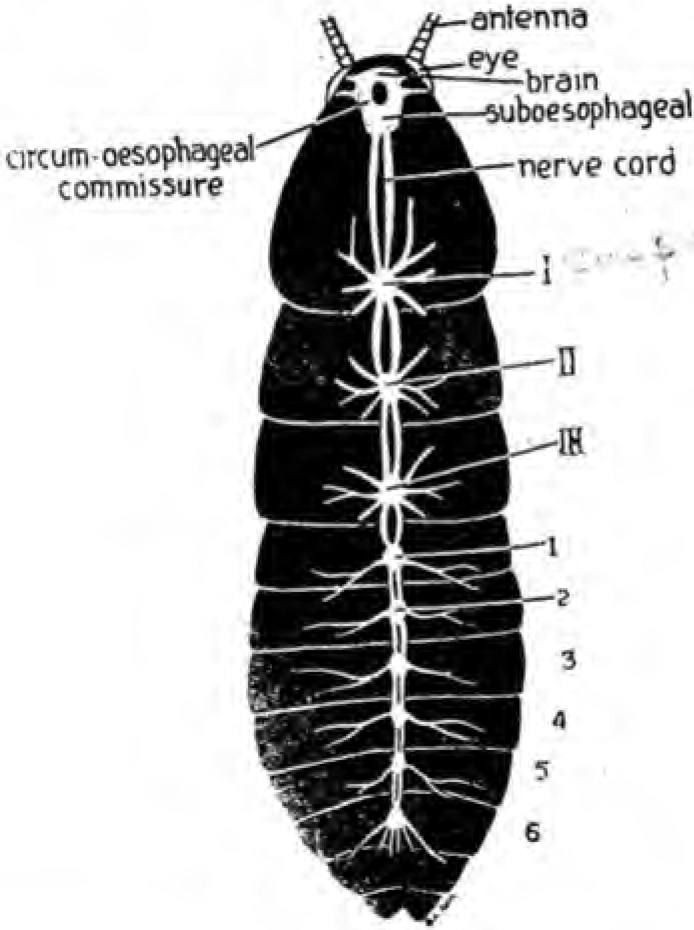


FIG. 245 *Periplaneta americana.* Nervous System in dorsal view.

The paired ventral nerve cord from the suboesophageal ganglion passes backward into the thorax. There are large paired pro-, meso- and metathoracic ganglia in the thorax. Each of these ganglia give off several paired nerves to the legs, wings, muscles, body wall, etc., and

are connected together by the ventral nerve cords. There is also one pair of ganglia on the nerve cords in each of the first six abdominal segments. The ganglia of the sixth segment is the largest of the abdominal ganglia. It represents the fused ganglia of the sixth, seventh, eighth, ninth and the other abdominal segments. It gives off nerves to the sixth segment and to the rest of the abdomen behind.

There is a ***sympathetic*** or ***stomatogastric*** system (Fig. 244). A ***frontal ganglion*** lies dorsally on the oesophagus in the head. A median unpaired ***recurrent nerve*** extends from this to the ***visceral ganglion*** on the crop. The visceral ganglion gives off nerve branches to the crop and gizzard. The frontal ganglion is connected with the central nervous system by nerves joining the circumoesophageal commissures.

Sense organs —The compound eyes (Fig. 246) are the most important of the organs of special sense. Each compound eye of the cockroach is composed of about 2000 hexagonal facets bounded externally by a transparent cuticle, the ***cornea.*** Each facet marks a single slender visual unit called ***ommatidium.*** An ommatidium consists of 1. the corneal facet externally, 2. a pair of ***corneagen cells*** which secrete the lens, 3. a crystalline cone of four conical cells, 4. ***distal pigment cells*** round the cone, 5. ***retinula*** of eight cells forming a central ***rhabdom,*** 6. basal pigment cells around the retinula and 7. a ***tapetum cell.*** The inner ends of the retinula cells are connected to nerve fibres, passing through ***optic ganglia*** to the ***optic nerves*** coming from the brain.

The formation of an image (Fig. 247) by such a complicated compound eyes is by two methods. When the cockroach is in strong light, the pigment extends and isolates each ommatidium from the adjacent ones. The light from a small area of the object is focussed by the conical lens on the retinula. A ***mosaic image*** is thus formed, light from different areas of an object is focussed in different ommatidia. This image is also called an ***apposition image.*** When the light is dim, the pigment retreats to the base of the ommatidium. The light rays therefore scatter from an ommatidium to the adjacent ommatidia. A continuous or a ***superposition image*** is thus formed on the retinulae of the ommatidia. This image is less sharp than the apposition image, but enables vision even in poor light. The compound eye is eminently adapted for detecting movement more efficiently than the eye of the frog.

The cockroach possesses a keen olfactory sense, which is located in the antennae. The sense of taste is also well developed. The tactile sense is perhaps the best developed of all in the cockroach.

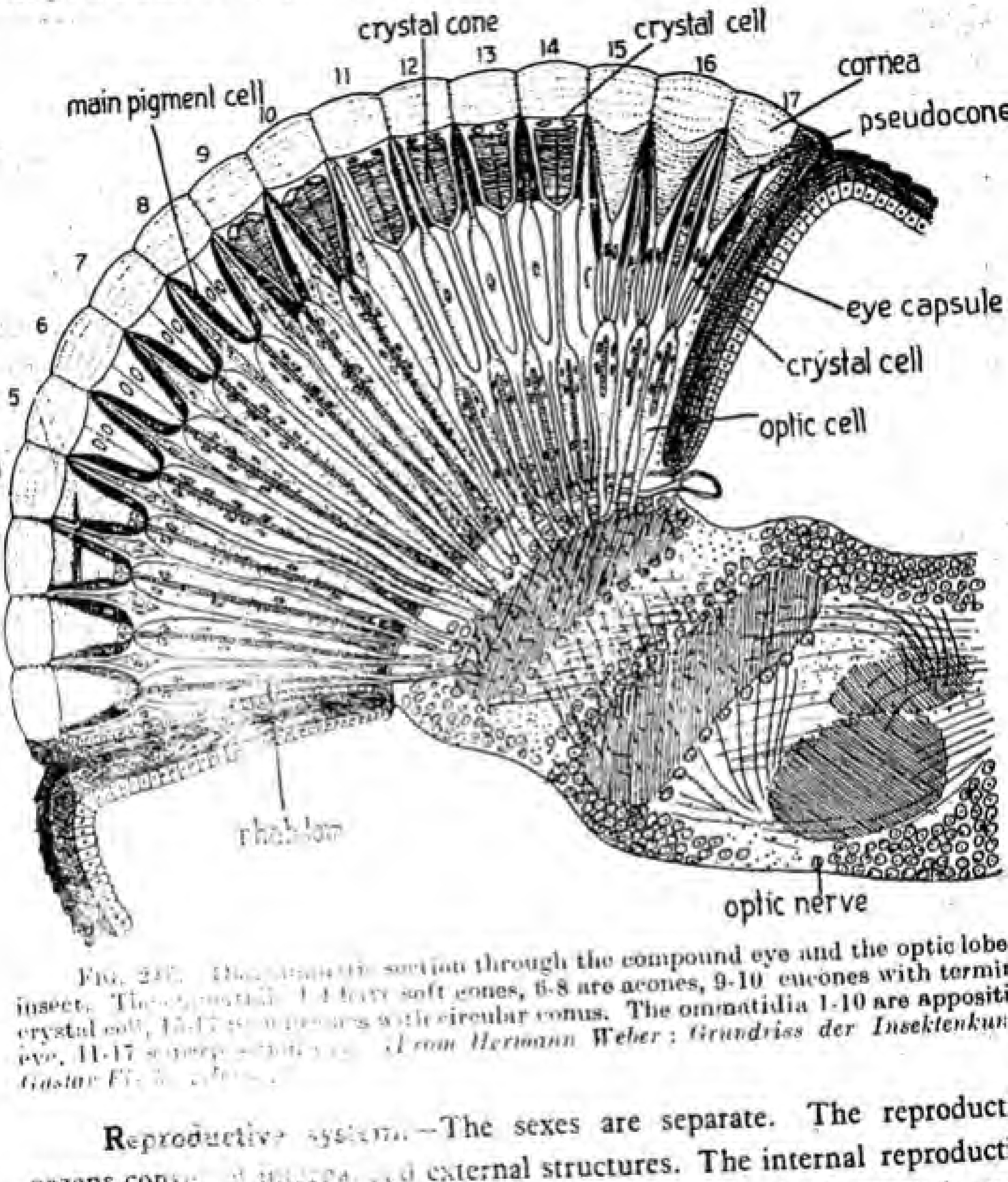


FIG. [illegible] Diagrammatic section through the compound eye and the optic lobe of insect. The ommatidia 1-4 have soft cones, 6-8 are acones, 9-10 eucones with terminal crystal cell, [illegible] with circular conus. The ommatidia 1-10 are apposition eye, 11-17 superposition eye. (From Hermann Weber: Grundriss der Insektenkunde, Gustav Fischer, [illegible])

Reproductive system.—The sexes are separate. The reproductive organs consist of internal and external structures. The internal reproductive organs in the female are a pair of ***ovaries*** (Fig. 248). Each ovary is composed of a number of ***ovarian tubules***, which are full of ova in various stages of development. The tubules are attached together anteriorly and posteriorly in a bundle but are free in the middle. The ovaries communicate with a short median ***uterus*** by a pair of oviducts. The uterus opens into the genital pouch by the ***vulva*** in the eighth abdominal segment. The duct of much branched ***colleterial glands*** opens into the uterus. A small ***spermatheca*** receives the sperms from the male during copulation.

The external reproductive organs of the female belong to the seventh, eighth, and ninth abdominal segments. These are modified: the eighth and ninth being tucked under the seventh which completely conceals them.

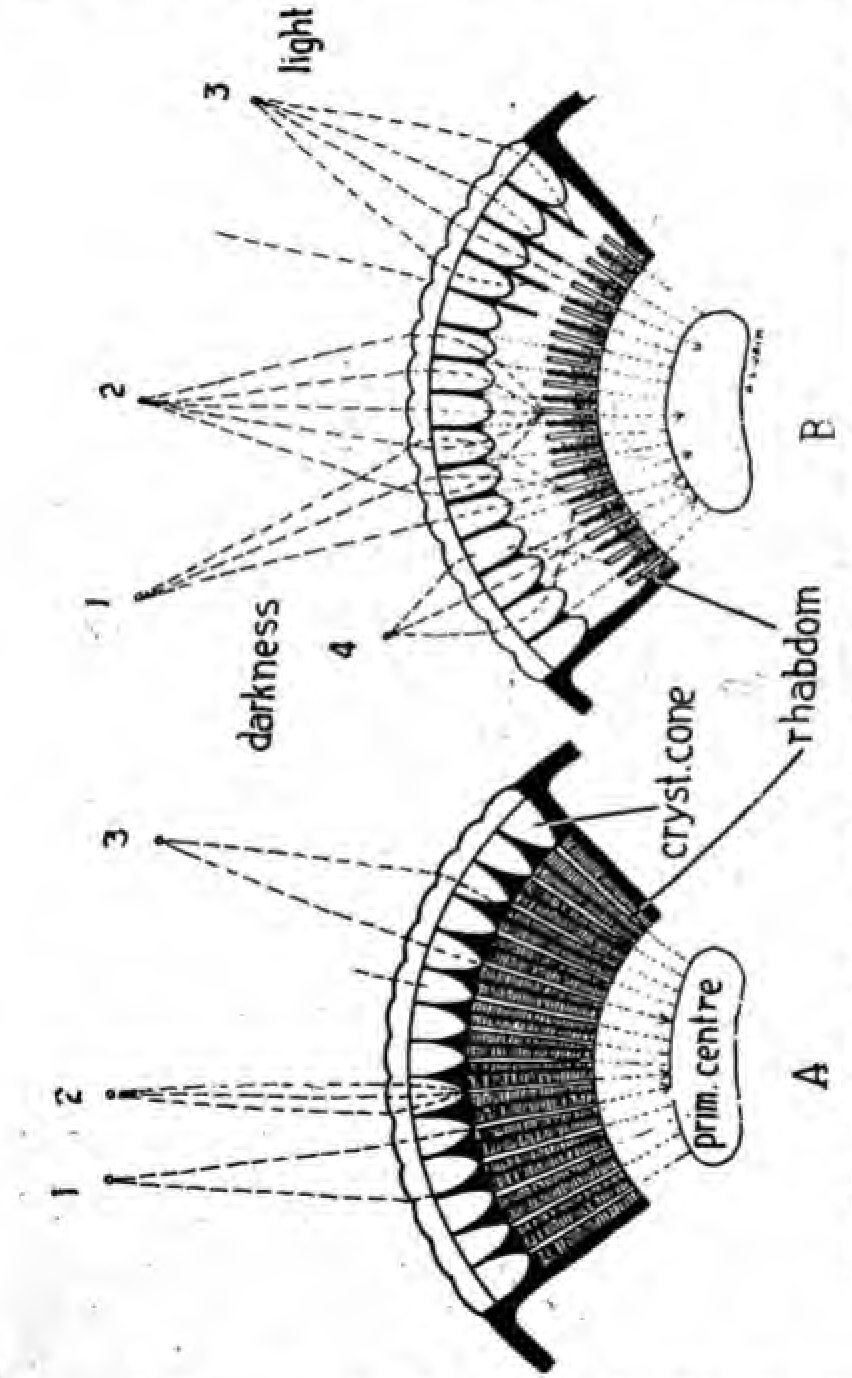


FIG. 247. Diagram of the path of light rays in A. the apposition compound eye and B. the superposition compound eye. Points 1-4 are sources of light. In the apposition eye only a narrow pencil of rays enters a rhabdom and thus the light from each point of source falls on only one retinule. In the superposition eye the different rays from a point source of light falling on different cones combine to enter one rhabdom: there is thus a superpositon of many images. This combining of many images is impossible at 4. In the apposition eye each ommatidium is optically isolated by dark pigment and forms an erect image of only one point of the object, so that a mosaic of numerous images results in the compound eye. In the superposition eye, essentially the eye for dim light, the ommatidia are not made light-tight by pigment. The light rays bend and converge in one rhabdom, so that a bright but diffuse image of a dim object forms on the retinule. (*From Hermann Weber: Grundriss der Insectedkunde, Gustav Fischer, Jena*).

A pouch-like space is thus enclosed: this is the genital pouch. The tip of the abdomen of the male is received in this cavity during copulation. The uterus opens into it anteriorly. The spermatheca also opens

into this pouch. The paired ***gonapophyses***, which are the modified appendages of the eighth and ninth abdominal segments, are lodged in the genital pouch. These two form a ***forceps*** used in grasping the egg capsule.

The internal male reproductive organs consist of a pair of ***testes*** in the fifth and sixth abdominal segments. The ***sperm ducts*** run backward to the seventh segment to open into the large ***mushroom-shaped glands***. The mushroom-shaped glands comprise the two ***seminal vesicles***, with projections filled with the sperm. The vesicles unite behind into a muscular ***ejaculatory duct*** opening to the outside. A ***conglobate*** gland lies below the ejaculatory duct. The external organs consist of a complicated set of plates and hooks.

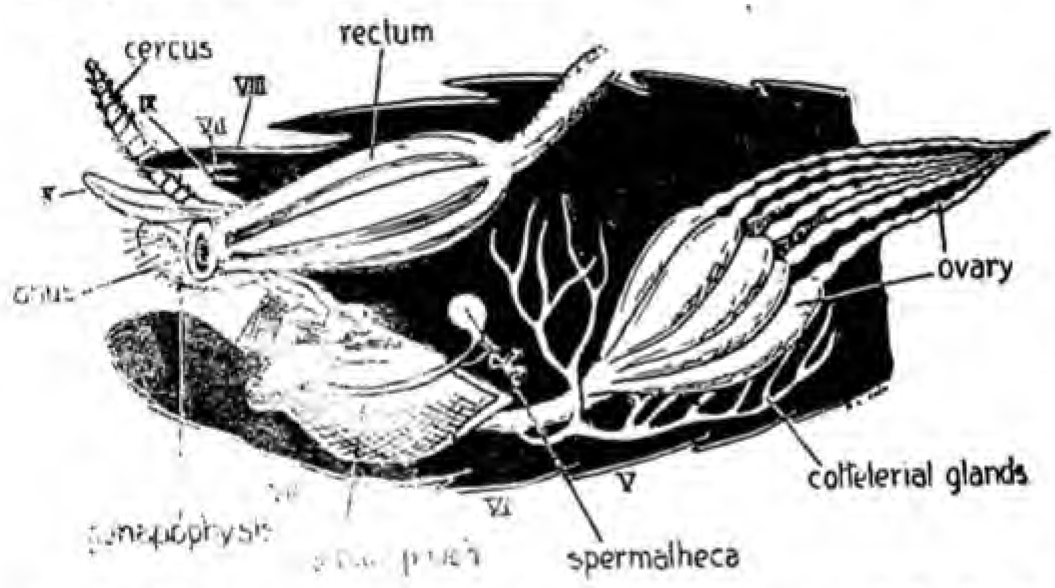


FIG. 248. *Periplaneta americana.* The reproductive organs of the female in lateral view.

The testes are functional only in the young male cockroach but are reduced in the adult. The mushroom-shaped organ takes on the work of supplying the sperm and is often mistaken for the testes.

Nutrition.—The cockroach is truly omnivorous. It is extremely fond of all sorts of kitchen refuse. It often chews off the starchy sizing of paper, book-binding, cloth, etc. Sleeping babies are frequently attacked by cockroaches, which eat away pieces of skin or the tender hairs on the head, eye brows, etc. The food is bitten off into convenient morsels and chewed into a pulp by the mandibles and maxillae. Copious flow of saliva lubricates the morsel and aids digestion. The chewed mass is swallowed and stored up in the crop till the feeding is over and to be digested at leisure. The digestive fluids from the midgut ascend up into the crop where the digestion com-

mences. The digested food is absorbed in the midgut. The saliva digests carbohydrates. The glucose that results is absorbed in the crop. The gizzard acts both as triturator and strainer. The hepatic caecae secrete a fluid which digests fats and proteids.

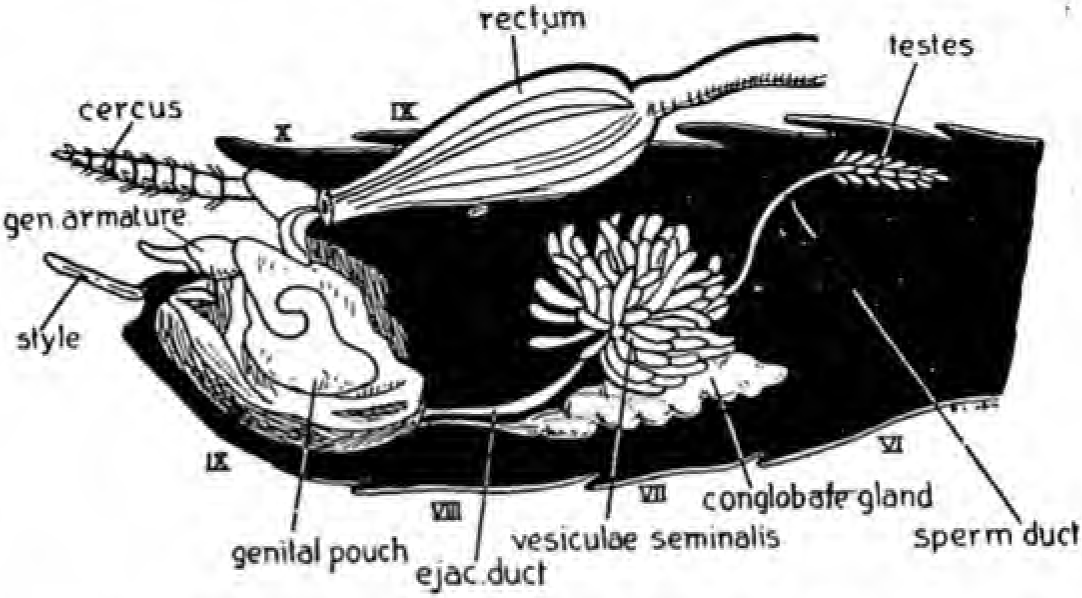


FIG. 249. *Periplaneta americana.* The reproductive organs of the male in lateral view.

Development.—(Figs. 250, 251). The ovum is fertilized within the uterus. It is covered by a thick outer chitinous ***chorion***. Sixteen eggs are packed together into a horny handbag-shaped egg case or ***ootheca***. The ootheca is carried in the genital pouch of the mother for several days. She conceals it under some crack or in some warm dark cavity.

The egg is rich in yolk, which is concentrated in the centre. The egg cytoplasm itself occupies the periphery (Fig 250). Such an egg is called ***centrolecithal***. The zygote nucleus is located in the middle of the yolk and is connected by protoplasmic threads to the peripherial cytoplasm.

The zygote nucleus undergoes segmentation and most of the daughter nuclei migrate to the surface protoplasm. The protoplasm divides into as many cells as there are nuclei. A ***blastoderm*** (Fig. 250) is thus formed around the yolk. The blastoderm cells on the concave side become thicker along a narrow band called the ***germ band*** (Fig. 250). The germ band gives rise to the future cockroach. The rest of the blastoderm is the outer embryonal envelope called ***serosa***. Gastrulation (Fig. 250) is a very complicated process and has given rise to conflicting views. The cleavage nuclei which remain behind in the yolk after the formation of the blastoderm represent the

primary endoderm (Fig. 250). Gastrulation however is not completed at this stage. A median longitudinal groove appears in the germ band. The edges of the groove form the ***lateral plate,*** which becomes the ectoderm.

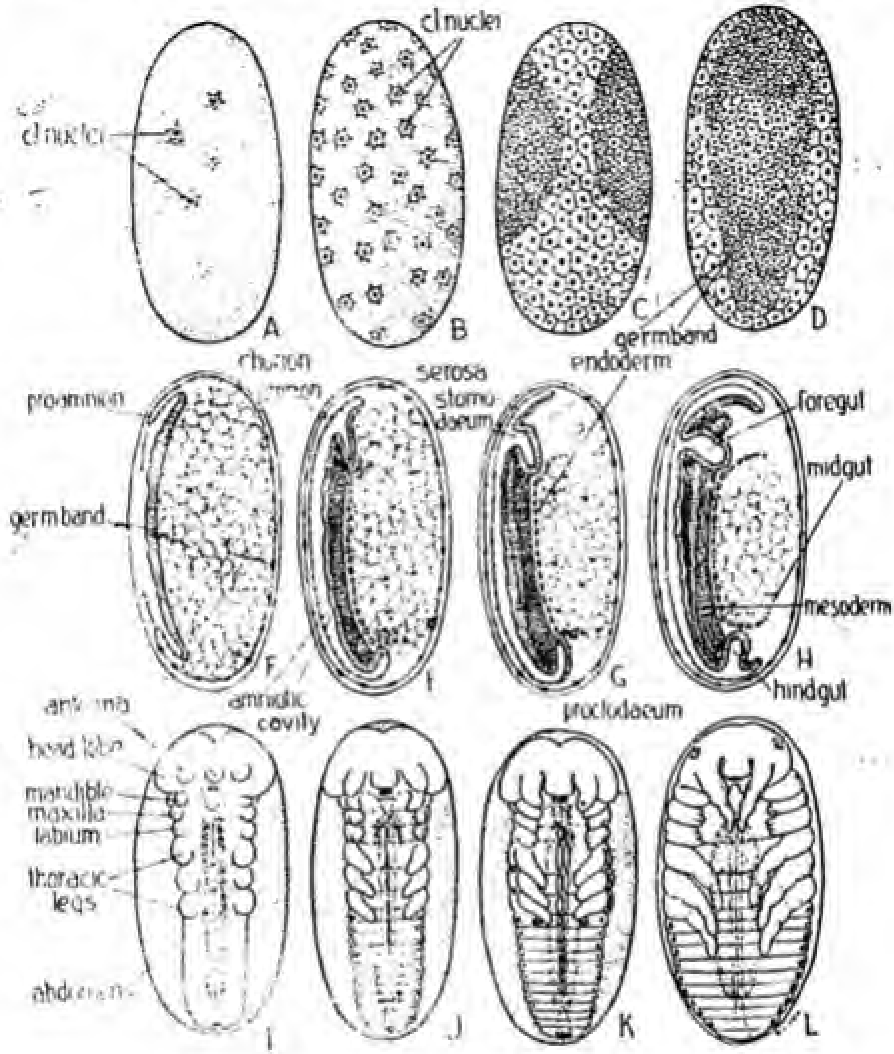


FIG. 250. Embryonic development of an insect. A-D. Successive stages in the cleavage and formation of the blastoderm and germ band. E-H. Longitudinal sections. E-F show formation of the embryonal envelopes on the superficial germ band. F-H show the differentiation of the mesoderm and endoderm, formation of ventral nerve cord and the stomodaeum and the proctodaeum. I-L. ventral view to show the successive stages of the formation of segments and appendages, J corresponds to E to F and L to G and H. (*From Hermann Weber: Grundriss der* [illegible])

The floor gives rise to the ***middle plate*** destined to form the internal organs. The endoderm forms the midgut. The ectoderm becomes invaginated into stomodaeum and proctodaeum. The midgut gradually grows over and encloses the yolk within. The head is first segmented off from the thorax, later the thorax and the rest of the body become segmented (Fig. 250). Each segment bears a pair of sac-like evaginations, which are the

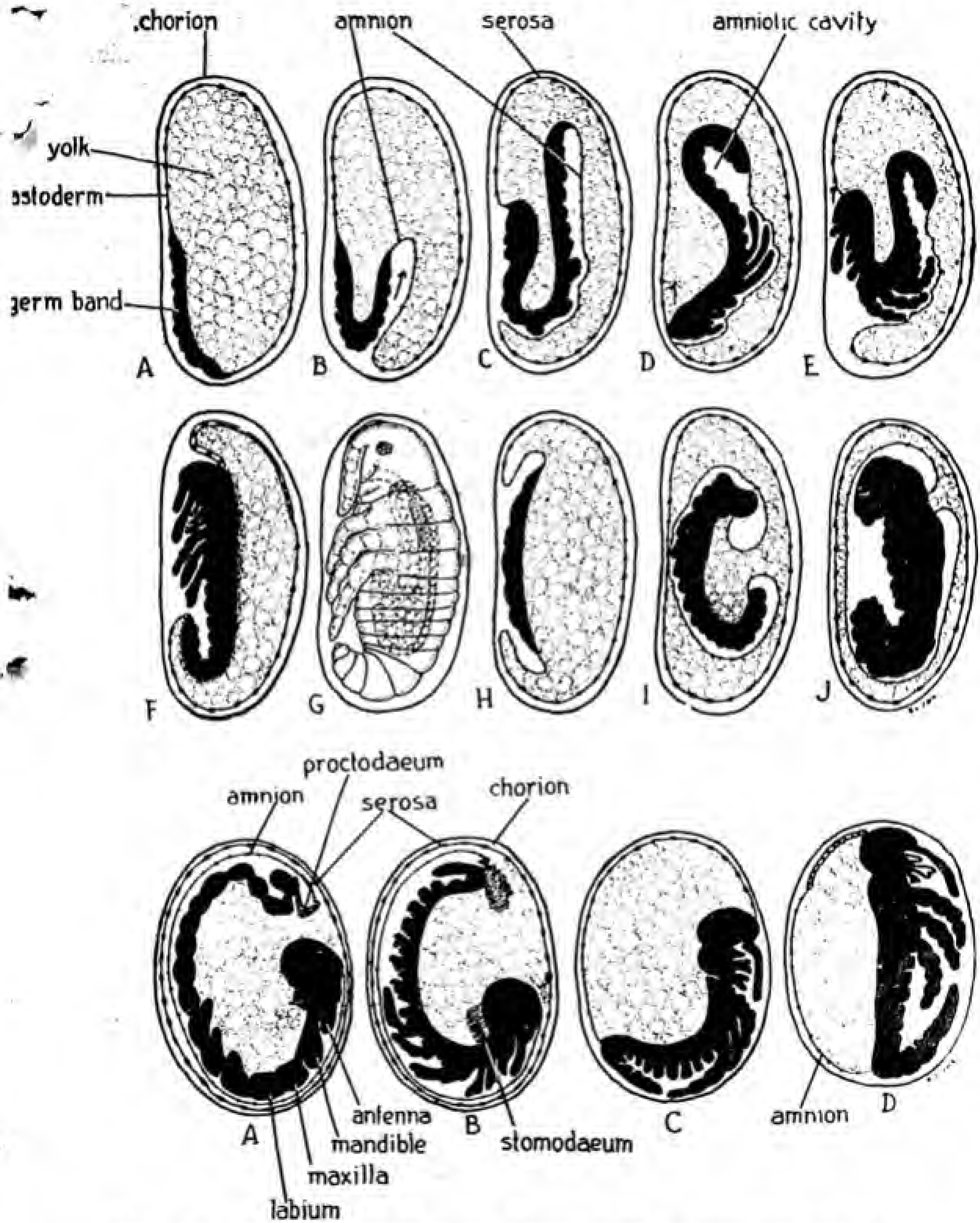


FIG. 251. Successive stages of the formation of the embryonal envelopes, amnion and serosa and different kinds of blastokinetic movements. (*From Hermann Weber : Gundriss der Insektenkunde, Gustav Fischer, Jena*).

rudiments of the appendages. The nervous system arises as ectodermal invagination. After the germ band is differentiated from the ***serosa*** another embryonal envelop called ***amnion*** (Fig. 251) is formed within the serosa. The embryo sinks within the yolk, makes a complete turn, so that the serosa grows over and becomes double-layered. The inner layer is the ***amnion*** and the outer is the serosa. These movements constitute ***blastokinesis*** (Fig. 251), which serve to expose a fresh surface of the yolk to the embryo.

The young cockroach hatches with nearly all the adult characters (Fig. 252). The gonads and the wings are undeveloped. The freshly hatched cockroach is called a ***nymph***. The nymph grows and moults several times before it finally becomes the adult.

Natural enemies.—The cockroach has numerous enemies from Protozoa to Chordata. *Entamoeba blattae, Gregarina blattidarum,* several Ciliata,

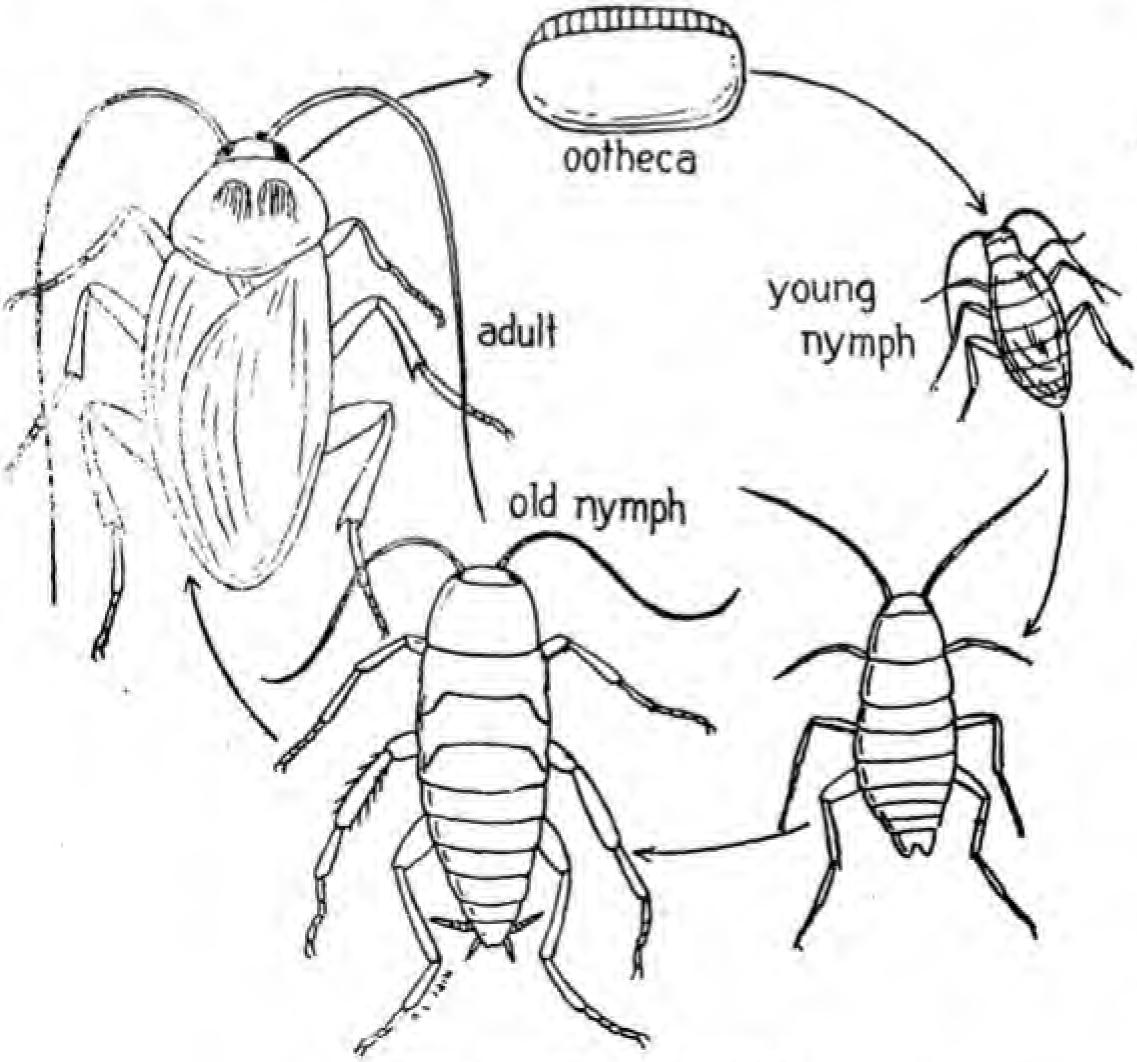


FIG. 252. Life-history of cockroach.

:matodes like *Oxyuris*, mites, insects like *Evania* are parasitic on : cockroach. Cockroaches are also attacked by birds, lizards and ıer animals.

Economic importance.—Cockroaches spoil and contaminate food. hey destroy binding of books, paper, etc. In several countries cockroaches :e eaten or prepared into "tea" and drunk. Cockroach tea is believed in :hina to cure certain diseases.

Resumé

I. Insecta

1. The insects are the most successful and dominant of all animals. They 'ar exceed in number all other animals combined together.

2. Insects are Arthropoda with the body segments specialized into head, ,horax and abdomen. They have only one pair of antennae and three pairs of legs. Many have one or two pairs of wings. Respiration is by means of trachea.

3. Insects are divided into thirty-four orders on the basis of differences in wings, mouthparts, metamorphosis, etc.

II. The Cockraoch

4. The cockroach belongs to the order Blattaria. The Blattaria are an ancient group of insects widely distributed all over the world.

5. The common domestic cockroaches are *Periplaneta americana*, *P. australasiae*, *P. brunnea*, *Blatta orientalis* and *Phyllodromia germanica*.

6. The exoskeleton of the cockroach comprises several plates movably articulated to permit movements.

7. The appendages of the head comprise the paired antennae and the mouthparts. The mouthparts include the mandibles, the maxillae, the labium and the hypopharynx, bounded in front by the labrum.

8. The legs and wings compose the appendages of the thorax. Except the anal cerci the abdomen lacks appendages.

9. The alimentary canal consists of a foregut, midgut and hindgut. The foregut includes a proventriculus for grinding the food.

10. Malpighian tubules are the excretory organs.

11. The circulatory system is poorly developed and comprises the dorsal heart and blood-body-space.

12. The respiratory system consists of much branched tubules that open to the outside by the spiracles. Air circulates in these tubules and reaches all parts of the body.

13. The nervous system is constructed on the same plan as in the earthworm. The sense organs include the compound eye.

14. The sexes are separate. The reproductive organs consist of the testes and ovaries.

15. The ova are centrolecithal and undergo superficial segmentation. A complicated gastrulation is followed by organ differentiation. A young nymph hatches from the egg and gradually reaches maturity.

CHAPTER XV

OTHER INSECTS

The cockroach, which was described in the last chapter, is a type of generalized insect. Other insects are specialized for different modes of lives. In many the antennae are reduced and short as in the housefly (Fig. 275) or plumed as in some gnats and moths. The mouthparts are modified for piercing or puncturing skins and sucking liquids (Fig. 259), as in bedbug (Fig. 258) and mosquitoes. Some never feed at all in the adult stage. The legs are adapted for jumping as in the grasshopper, for digging as in the mole cricket or swimming as in waterbugs. The wings are greatly modified: in the beetles the fore wings are hardened as ***elytra*** and are useless in flight, in flies the hind wings are reduced to knobbed ***halteres***. In butterflies the wings are covered by ***scales*** (Fig. 268 B) that give the beauty and colour to these insects. Several other insects are devoid of wings, *e. g.* the bedbug, head and body lice (Fig. 257), rat flea (Fig. 231), etc. Many can produce sounds and have ears on legs or on the abdomen. The fireflies produce light. In addition to the usual method of reproduction after fertilization, many insects reproduce ***parthenogenetically*** (*i. e.* unfertilized eggs develop) or ***paedogenetically*** (larvae reproduce without fertilization). Some wasps exhibit ***polyembryony:*** a single zygote divides into 100 or more embryos, each of which becomes an adult. Insects parasitize other insects; many parasitic insects are themselves parasitized by ***hyperparasites.*** From the stand-point of man, insects can be broadly grouped as 1. neutral, 2. beneficial, 3. useful and 4. harmful.

1. The majority of insects are of no importance to us. They do not cause any damage to crops or otherwise harm man. Their activities do not also benefit us. These are of neutral value.

2. Beneficial insects are enemies of those insects which are injurious to **man.** Insect parasites and predators destroy large numbers of pests of crops or of domestic animals and of man. The praying mantis (Fig. 231) and dragonflies (Fig. 233) hunt flies and mosquitoes and thus do considerable good.

3. Useful insects supply us with food, clothing, medicines or other products. Honey, silk, lac, cantharidin are valuable products obtained from insects. Some insects like termites, grasshoppers, beetle grubs are

also eaten in several countries. Others like *Drosophila* have helped men in understanding the complicated laws of heredity; they are used in scientific investigations.

4. Harmful insects destroy our crops, spoil stored food, clothing, furniture, books and other products. They bite and suck the blood of man or of his domestic animals. They act as intermediate hosts for pathogenic agents like the malarial parasite, plague germ, etc. Most epidemic diseases are insect-borne. Several of them also attack useful and beneficial insects. In short, they interfere with some desired object of man. If the damage caused by them becomes considerable and causes heavy monetary loss, they become ***pests***. Locusts and mosquitoes are for example two notorious world pests, which have caused more famines and loss of lives than any other cause.

APTERYGOTA

Order THYSANURA

Silverfish

Lepisma saccharina, the common "silverfish" is one of the household insects (Fig. 253). It is a glistening silvery-white, fish-shaped insect, with long antennae, three caudal appendages, biting mouthparts and covered by scales. Though devoid of wings, it is not a primitive insect: in many respects it comes close to the higher insects. It is abundant in warm moist places among books, pictures, papers, clothes, etc. When exposed to strong light or otherwise disturbed, it runs very rapidly to a place of concealment. The silverfish feeds on starch, dry food stuffs containing starch, glue and paste used in book-binding, starched clothing, paper, etc.

PTERYGOTA

Order SALTATORIA Obsolete

Locust

Locusts are grasshoppers. Most grasshoppers are solitary and resident insects but locusts are grasshoppers that become gregarious and migrate in swarms. Grasshoppers occur all over the world. They feed on practically any leafy vegetation. They have long slender bodies, biting and chewing mouthparts and powerful hindlegs adapted for jumping. The males produce sound by ***stridulation*** or rubbing of one part against another.

There are many locusts but *Schiostocerca gregaria*, the desert locust, and *Locusta migratoria*, the migratory locust, have been known

from time immemorial. They are the most destructive of all insects. The desert locust is distributed in tropical Africa, N. Africa, Arabia, Palestine, Persia, Afghanistan, Pakistan and North-west India. It is permanently resident in desert areas and when conditions are favourable,

FIG. 253. *Lepisma*, the 'silverfish' that hides under pictures and wall paper and feeds on starchy matter.

reproduces enormously and passes into the gregarious phase at periodical intervals. There is then a swarm that migrates to other areas, devouring every thing green and laying waste thousands of square miles. The migratory locust occurs practically all over the Old World.

Grasshoppers and locusts lay eggs underground by drilling a hole by the abdomen. The eggs are elongate and enclosed in a cementing secretion that hardens to produce an egg-packet. The young nymphs resemble the adults generally except in size, and develop gradually, moulting four or five times. Metamorphosis is gradual. Some locusts pass through

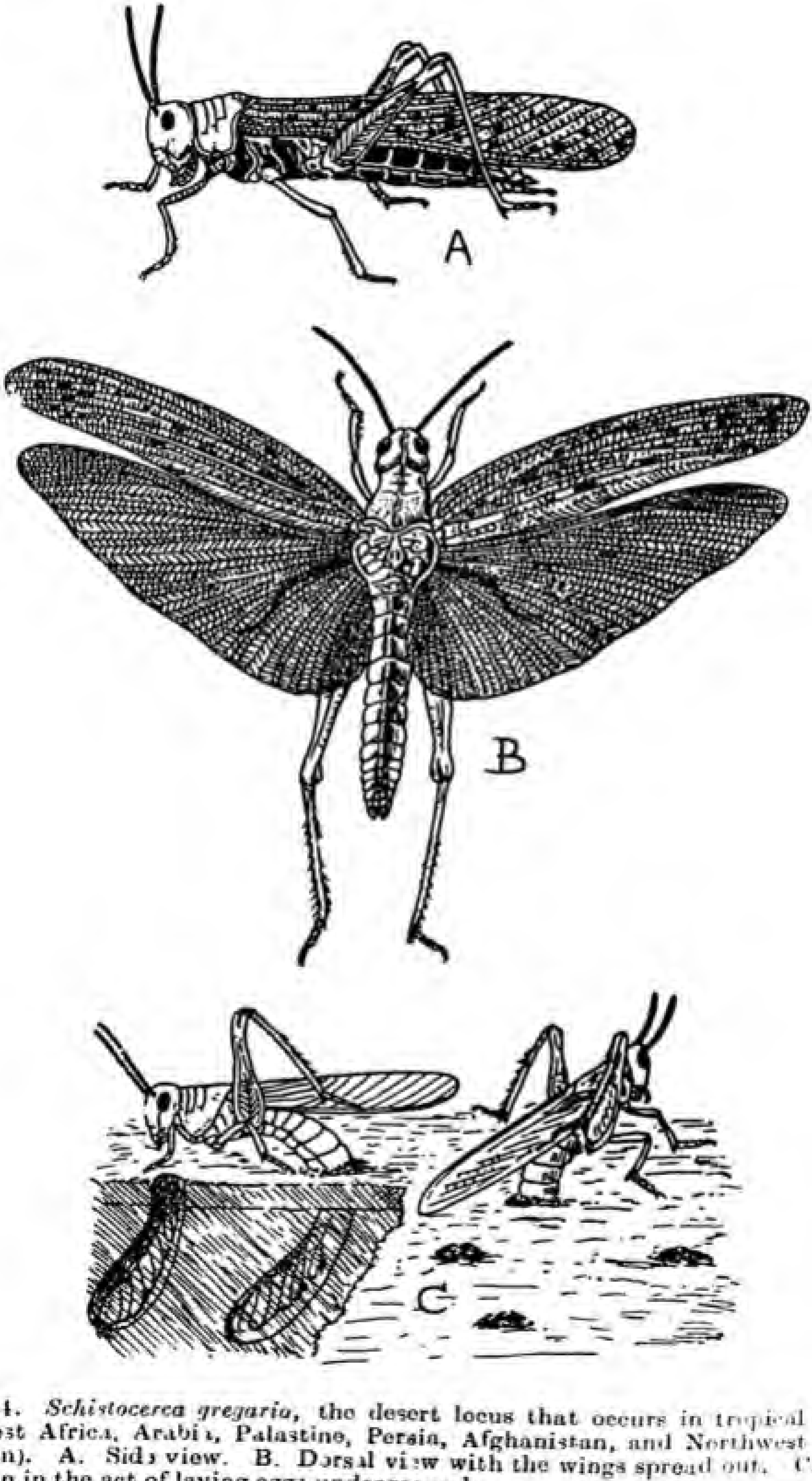


FIG. 254. *Schistocerca gregaria*, the desert locus that occurs in tropical North and Southwest Africa, Arabia, Palestine, Persia, Afghanistan, and Northwest India (now Pakistan). A. Side view. B. Dorsal view with the wings spread out. C. Two females shown in the act of laying eggs underground.

regular cycles of solitary, gregarious and migratory phases, so that locust swarms appear at regular intervals. Others are irregular. The laws that govern the swarming are not still clearly understood. It is not food that urges them but some other deep-rooted cause. Locusts do not recognize political borders but migrate freely from one country to another. An international organization of entomologists studies locusts in their breeding grounds and issues warnings of an impending swarm.

Cricket

Crickets (Fig. 255) differ from grasshoppers and locusts in having long antennae and elongate ovipositor. The tympanum is located on the fore tibia. Like grasshoppers, crickets can also jump and have strong hindlegs. They love warmth and hide in holes undergound, in cracks and crevices, behind boxes and books, in chimneys, ovens and similar situations in kitchens and bakeries. During warm weather they usually live outside but come indoors in winter.

Cricket sproduce the familiar monotonous intensely shrill chirping at night. The sound is extremely difficult to locate. The song of the cricket is produced by rubbing together the outer pair of wings which bear special structures. Only the males can sing. Crickets are very elusive and difficult to locate.

Crickets are truly omnivorous and frequently damage woollen, silken and cotton clothing, paper, fruits, vegetables and other food materials. They also nibble off pieces of skin or hair from sleeping babies at night and cause intense burning sensation. Some, like the mole-crickets, burrow underground and have the fore legs specially adapted for digging. The femur is short and swollen, with a tooth in front at the base, tibrae are short, [illegible] and toothed and the tarsi short and dentate.

Order ISOPTERA

Termite

Termites are small soft-bodied, mostly subterranean, social insects. Because they live in perpetual darkness, they are pale (hence the popular misnomer white-ants) and are often blind. Mouthparts are for biting and chewing ; the mandibles are frequently enormous. The two pairs of wings are similar and are folded flat on the body when at repose. Termites are polymorphic and include the castes of queens, males, winged and short-winged forms, soldiers and workers, which differ very much in shape, size and structure. The fertilized queen termite is a wingless grub-like form (Fig. 256) that is merely a bag of eggs. She is quite helpless

and her only function is laying eggs. She lives on for as many as fifteen years and produces over one million eggs. The termite is the most

FIG. 255. The common house cricket has strong hind legs and like the grasshopper can jump. It hides under stones and holes in the pantry and [illegible]. It makes the familiar chirping noise, the blended sounds of which rise and [illegible] rhythm.

prolific of all insects. Immediately after the first rains, immense numbers of winged males and females emerge from their subterranean burrows in great swarms and fly to light at night. This is the great nuptial flight of termites. Thousands are devoured by lizards, birds, ants, etc. Soon

they shed their wings, copulate and retire to a safe place to found a new colony.

Termites devour everything and cover them with mud cemented with saliva. They are very destructive to timber and other woodwork, books, clothes, etc. They are able to digest cellulose and convert it into sugar with the help of symbiotic Protozoa which live in their intestine. They also culture fungi.

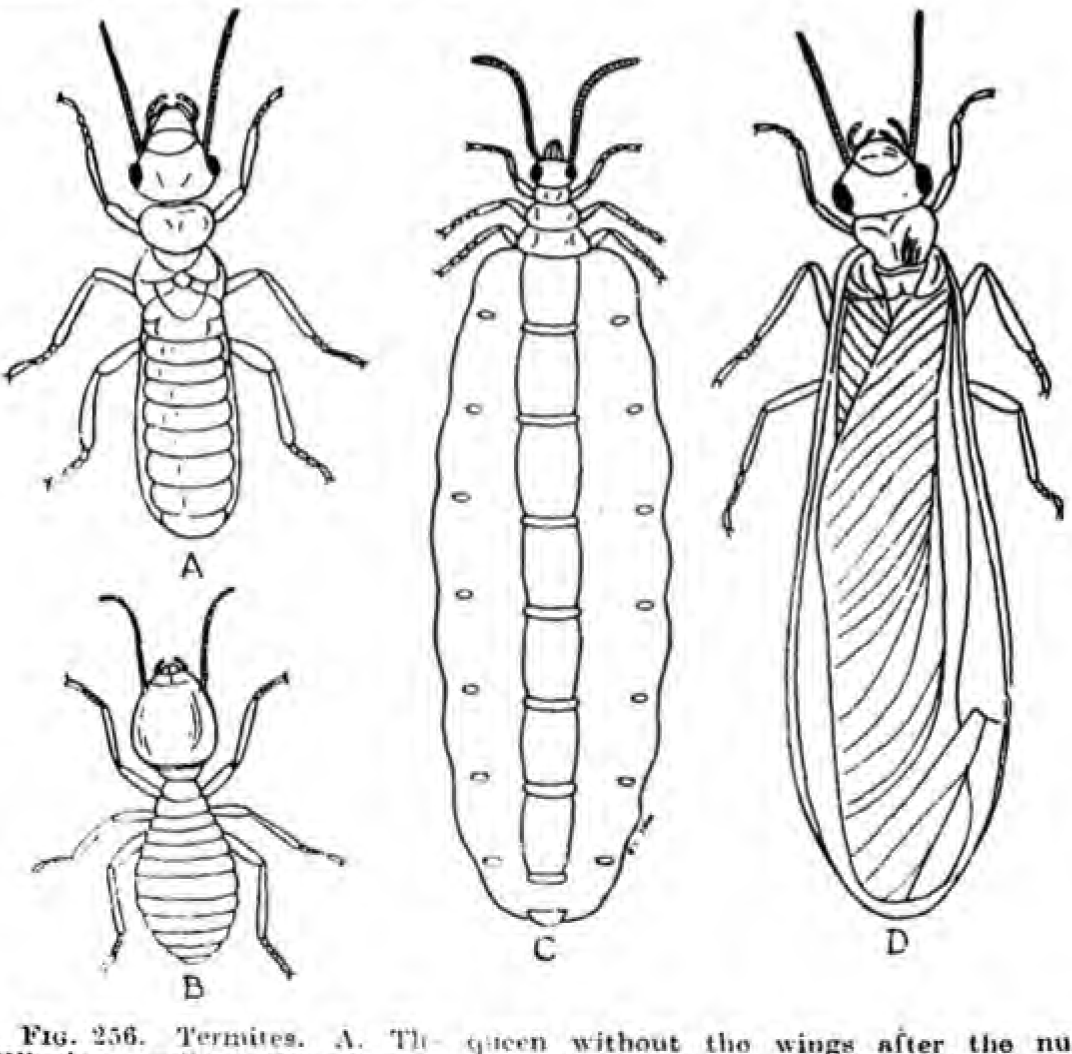


FIG. 256. Termites. A. The queen without the wings after the nuptial. B. Wingless sterile worker, that gathers food, cares for the young, builds mounds and does all work of the colony. C. The mature queen merely a swollen abdomen nothing that is but a mass of eggs, her only task in life is to lay eggs. D. The winged virgin queen before her nuptial.

Some of them build enormous mounds of earth above ground. These mounds change the landscape and form conspicuous land-marks in the tropics.

The termitoria or the termite "hills" of some species are so gigantic that the inhabitants of the Belgian Congo clear them of the

termites and use them as dwellings for themselves. They are frequently thirty feet high and strong enough to resist tropical weather.

The life-history is extremely complicated and is not fully understood yet in several cases. Several insects like flies, crickets, etc. live as guests in the nests of termites and are called ***termitophilous*** insects.

Order ANOPLURA (Siphunculata)

Lice

The Anoplura include the minute, flat, wingless lice, which are ectoparasites of mammals, with reduced or obsolete eyes and sucking mouthparts. The tarsi have only one segment, which is modified for holding on to the hairs (Fig. 257). They thrive on people living in unclean and over-crowded environment. There are three lice which attack man and suck his blood : 1. *Pediculus humanus capitis* the head-louse, 2. *P. humanus vestimentorum* the body-louse, and 3. *Phthirius pubis* the crab-louse.

The head-louse occurs all over the world and is an ectoparasite on the head of man. It is white, brown or black. The female is about two millimetres and the male 1.5 mm. long. The legs are adapted for clinging to hairs. The eggs are attached to the hairs by a collar-like cementing material. The eggs incubate for about a week and the young louse gradually reaches maturity. It is more frequent in women than in men.

The body-louse resembles the head-louse but has longer antennae. It lives on the neck, throat and trunk and clings to the clothing next to the skin, *e. g.* underwears. It attacks old and emaciated persons. The eggs are also laid on the clothing or on the body hairs.

The head and body-lice are of importance not only from the standpoint of cleanliness and of comfort, but also because they act as vectors for fatal diseases. The punctures made by the lice set up severe irritation, which leads to violent scratching. The lice transmit the germs : *Rickettsia provazeki* of typhus, *R. quintanae* of trench fever and *Spirochaeta recurrentis* of recurrent fever.

The crab-louse is smaller than the head or body-lice and resembles a tiny crab in general appearance. It is also called pubic-louse, because it is usually found in the pubic region. When numerous, it ascends up to the arm pit. It never occurs on the head. Its legs are large, the hindlegs being armed with powerful claws for clinging to the hair. It adheres close to the skin, imbeds its mouthparts and remains feeding in one place for several days. It sets up intense irritation, especially at night. It is not known to transmit any disease.

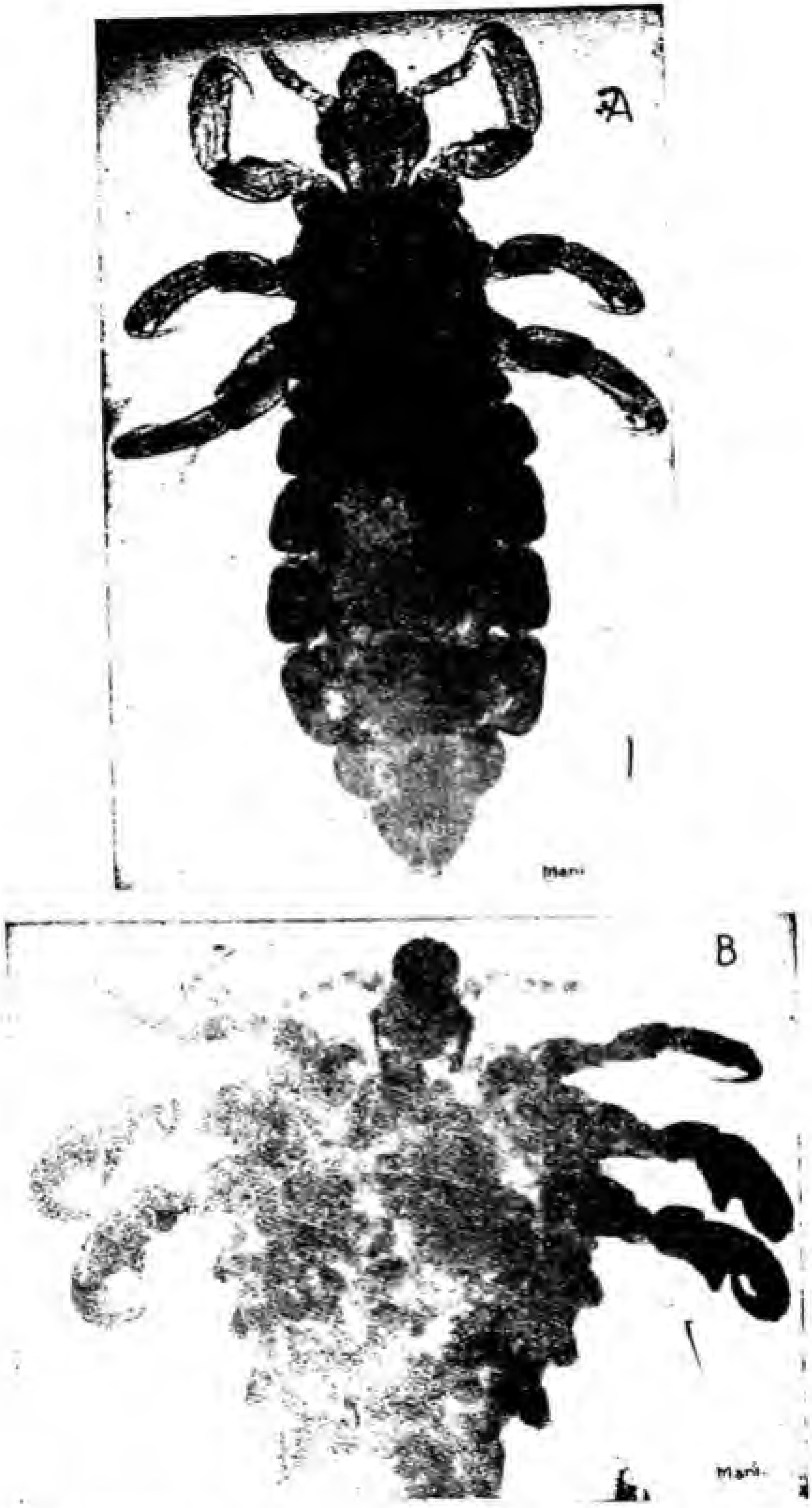


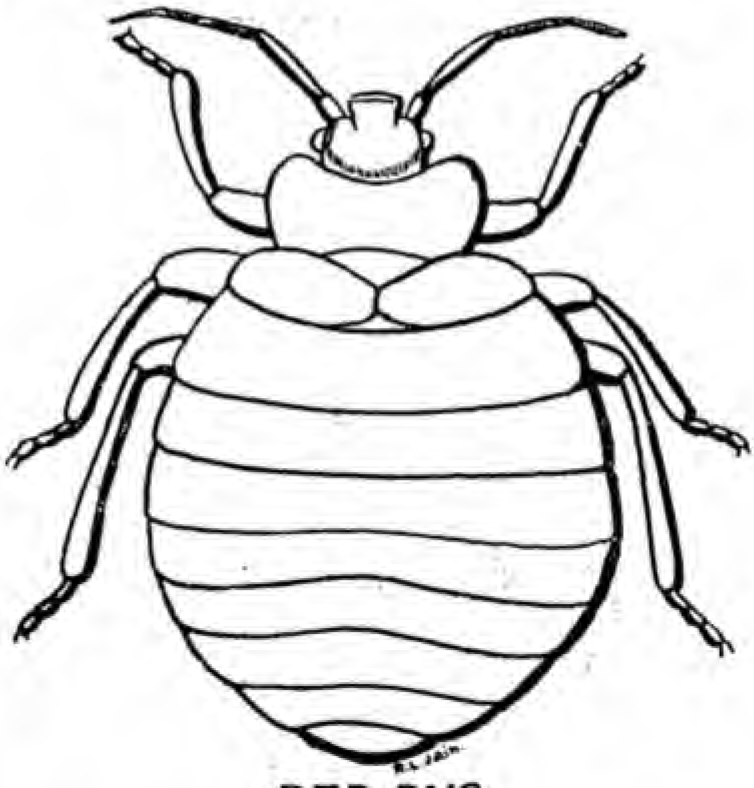
FIG. 257. Human lice. A. *Pediculus humanus capitis* the head louse. B. *Phthirius pubis* the pubic louse. Lice are loathsome ectoparasites of man and have their legs adapted for clinging to the hair.

Order HETEROPTERA (Hemiptera)

Bedbug

The common bedbug has been known from time immemorial. It is widely distributed all over the world. It is the most annoying of the household pests which attack man. It is found in old buildings, hotels, railway carriages, old fashioned street cars and almost anywhere else.

The bedbug belongs to the order Hemiptera and possesses piercing and sucking mouthparts. *Cimex lectularis* is common in America, Africa, Europe, N. India, Siberia, N. China and Australia. *C. hemipterus* (formerly called *C. rotundatus*) occurs throughout India, Burma, Malaya, S. China and central Africa. Other closely related species of *Cimex* are ectoparasites of bats.



BED BUG

FIG. 258. Class Insecta. Order Heteroptera. The bedbug is a loathsome ectoparasite that sucks blood of man. All his cousins suck the blood of bats.

Structure. — Bedbugs are oval, flat, reddish-brown, wingless insects, possessing a peculiar stinking odour. The short and broad head bears a pair of four-jointed antennae and prominent compound eyes. The mouthparts are modified for piercing the skin and sucking the blood. A ***rostrum*** or beak encloses the needle-shaped ***stylets*** which pierce the

skin. The rostrum is a hollow sheath composed of the labium, elongated and modified into a tube. The cibarium is modified into a sucking pump. The mandibles are elongated into needle-shaped stylets, barbed apically to aid in making a puncture. The maxillae are also elongated into two tubes, a large one through which the blood is sucked up and narrow one down which the saliva flows. The bug places the tip of the rostrum on a suitable spot on the skin, the mandibular stylets make a punture and the maxillary stylets are thrust into the wound. The saliva then flows into the wound and prevents the clotting of the blood. The mixture of blood and saliva is then sucked up by the expansion of the cibarium. The roof of the cibarium is raised by the dilator muscles, thus enlarging the cavity. The blood rushes up into the increased space and passes into the oesophagus.

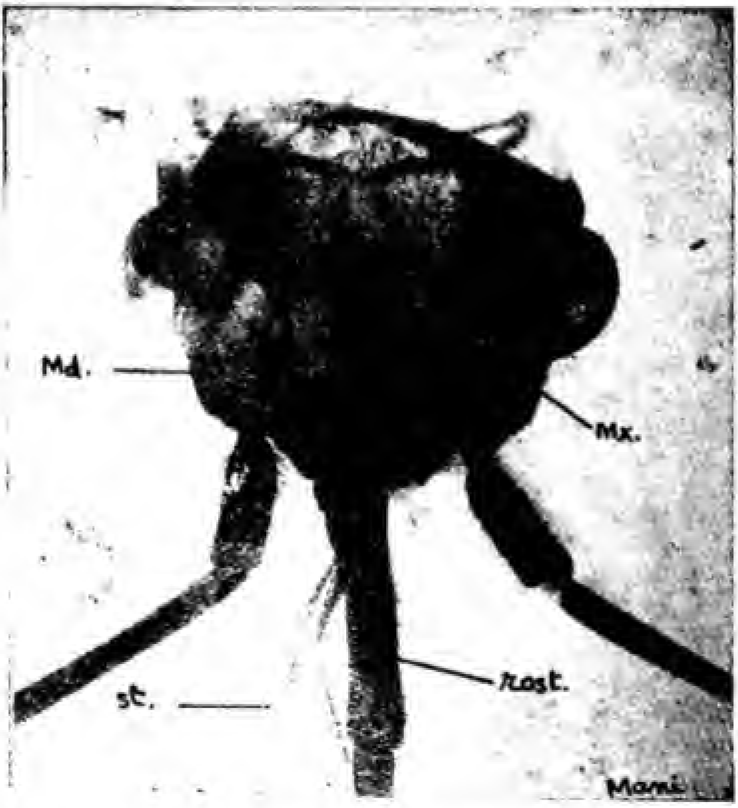


FIG. 259. The head of a bug showing the mouthparts. *md.* mandibular stylet. *mx.* maxillary stylet. *rost* rostrum. *st.* the piercing stylets outside the head.

Life-history.—The elongate oval whitish eggs are already in an advanced state of development when laid. They are provided with a cap-like lid which is pushed off by the young bug when hatching. Numerous eggs are thrust in holes, cracks, crevices, under mattreses, in pillow corners and woodwork. A single female lays about 200 eggs,

at the rate of 2 or 3 a day. The eggs hatch in about a week. The young bug is called a nymph and has the same general appearance as mature bug but is paler and smaller. It is capable of living without food for severel weeks. Soon after hatching it however runs away to have its first blood meal. If man is not ready at hand it will feed on the blood from the older bugs. It moults 5 times before becoming an adult.

Bugs can feed on rat, mouse or rabbit. Adults can survive starvation for six months.

Behaviour.—Bedbugs are nocturnal but often move about during the day. Starving bugs come cut openly even during the day time to feed. They also resort to cannibalism. Bugs are strongly attracted by warmth and body odour. They are capable of migrating from one house to another. If prevented access to beds by water troughs or other barriers, they climb up the ceiling to drop down from there on the bed! They also quickly run away after biting a man.

Natural enemies.—The bedbug seems to have few natural enemies. Common insectivorous animals like the lizard do not touch them, possibly because of the offensive buggy smell. It is said that cockroaches frequently attack bedbugs. Other larger bugs like *Reduvius personatus* are also natural enemies of the bedbug. In the Mediterranean countries the spider *Thanatos flavidus* destroys bugs.

Importance.—Bedbugs are undoubtedly the most detestable of the blood-sucking parasites of man. Bedbugs have been shown to be capable of transmitting *Leishmania donavoni*, *Spirochaeta recurrentis* and *Bacillus leprae*. The irritation due to the bite causes sleeplessness and contributes to ill-health.

Order HOMOPTERA

Lac Insect

Laccifer lacca, the lac insect is a highly specialized bug, the body of which is enclosed in a resinous or lac cell. They are minute and team in hundreds of thousands on banyan, *Schleichera trijuga*, *Acacia catechu*, *Butea frondosa*, *Zizyphus jujuba* and other plants in India. The females are irregularly globose without legs or wings. The males are winged or apterous. Reproduction is viviparous, sexual and parthenogenetic. The lac is gathered by breaking off the incrustation from the twigs and melting in boiling water. The product is ***shellac***. A red dye is also obtained for dyeing silk. Lac has been cultivated in India since very early times. In the *Adiparva* of the MAHABHARATA the Kauravas

FIG. 260. Ins[illegible] [illegible] cases of mud, paper and other materials. A. The [illegible] wasp. B. The paper comb of a s[illegible]cial wasp. Both belong to [illegible]

are mentioned as having built a house of lac, to burn away their enemies, the Pandavas. Shellac is used in the manufacture of toys, bangles, sealing wax, varnishes, insulating material, gramaphone records, shoe blacking, etc. Plastics have not succeeded in replacing shellac.

The lac insect is subject to the attack of several natural enemies, the most important of which is the caterpillar of the moth *Eublemma amabilis*, which devours the females.

Order HYMENOPTERA

Ants

The ants are the most familiar insects. They are everywhere : from the frigid to the tropic zones, in the deserts, forests, fields, hills and in our homes. The ants outnumber as individuals all other animals. They have deservingly attracted the admiration of man by their industry and

FIG. 261. Rain clouds gather and ants hurry into their burrows

selfless devotion to the welfare of the colony. All ants are social insects, with a wonderfully developed caste system, comprising workers, soldiers, queens and males. There is very great polymorphism. Wings are present in sexually mature forms but never in workers. The head

is large and has a relatively highly developed brain. Ants take care of all stages of their young, carry them, clean, protect and feed them.

The winged males and females (queens) swarm and mate. The males die and the females break off their wings and burrow underground. The queen remains in solitary confinement in an underground chamber and starts egg laying. The first larvae that hatch out are fed and cared for by her till they become workers. These now go forth in search of food, enlarge the nest and take on all the multifarious duties of feeding the queen and the young ones, cleaning and guarding the nest and so on. The queen now does nothing but lay eggs during all her life of fifteen years or so. In some ants a group of workers accompany a new queen to a fresh site for founding the colony and help her in her work. The nests are located underground, in hollow stems, or inside webbed leaves (Fig. 262).

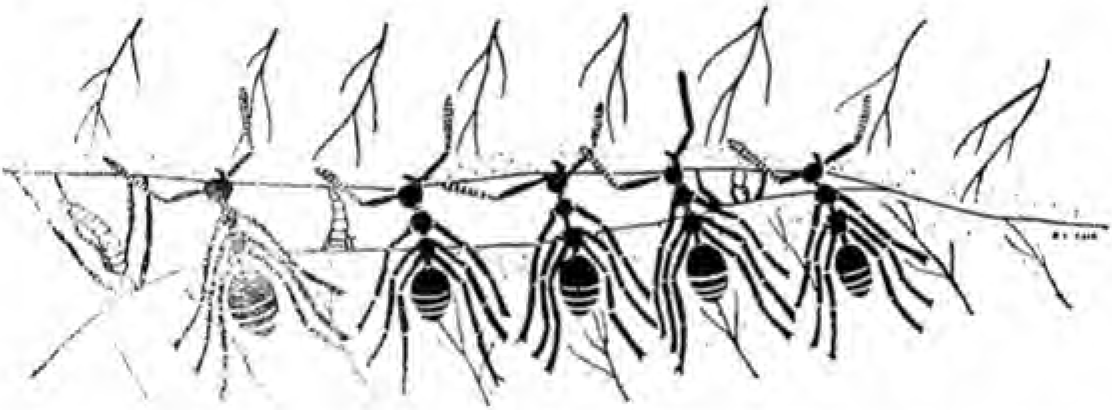


Fig. 262. Ants employing their larvae as living shuttle-cocks to spin silken threads and hold together the edges of leaves into a nest. One set of workers hold the edges together and another carry the larva from edge to edge.

Ants are omnivorous. They hunt all sorts of animals, which they overwhelm by their numbers. Others gather seeds and fruits for food. The common harvesting ant *Holcomyrmex* scatters the seeds of particular kind of grass about their nests during the monsoon, harvest the crop of grains in due time and store them up for future use as food. They strew the chaff in great piles outside their nests. Some like the leaf-cutting ant, raise fungi upon which they feed. They sally forth in large numbers, climb trees and cut off pieces of leaves. These pieces are dropped down to the ground, where a relay of workers pick and carry them off to the nest. The pieces are stored in special galleries and inoculated by the ants with the spores of a fungus. The fungus which grows on the leaves forms the food of the ants. A number of them have domesticated phytophagous

"Bee colony" won Stalin prize for popular science ...ies.
student of zoology should read this indispensable book

quantities of honey. *A. indica* is smaller and has been domesticated. *A. florea* is the smallest bee and its combs are often fixed in bushes. It stores a small quantity of honey.

FIG. 2[illegible]. Honeybee workers. A. *Apis indica*. B. *Apis dorsata*. C. *Apis florea*.

Honeybees live in permanent colonies comprising many individuals of three ***castes***: the ***queen*** who *alone* lays eggs, the ***drones*** are males that fertilize the queen and thousands of ***workers*** who construct the hive, guard it, go out foraging for pollen and nectar from flowers, attend on the queens and young ones The workers are infertile females, which do not reproduce. The workers and queen have stings: the workers use the sting against any enemies. The queen never stings man; she uses the sting only in fighting with another queen.

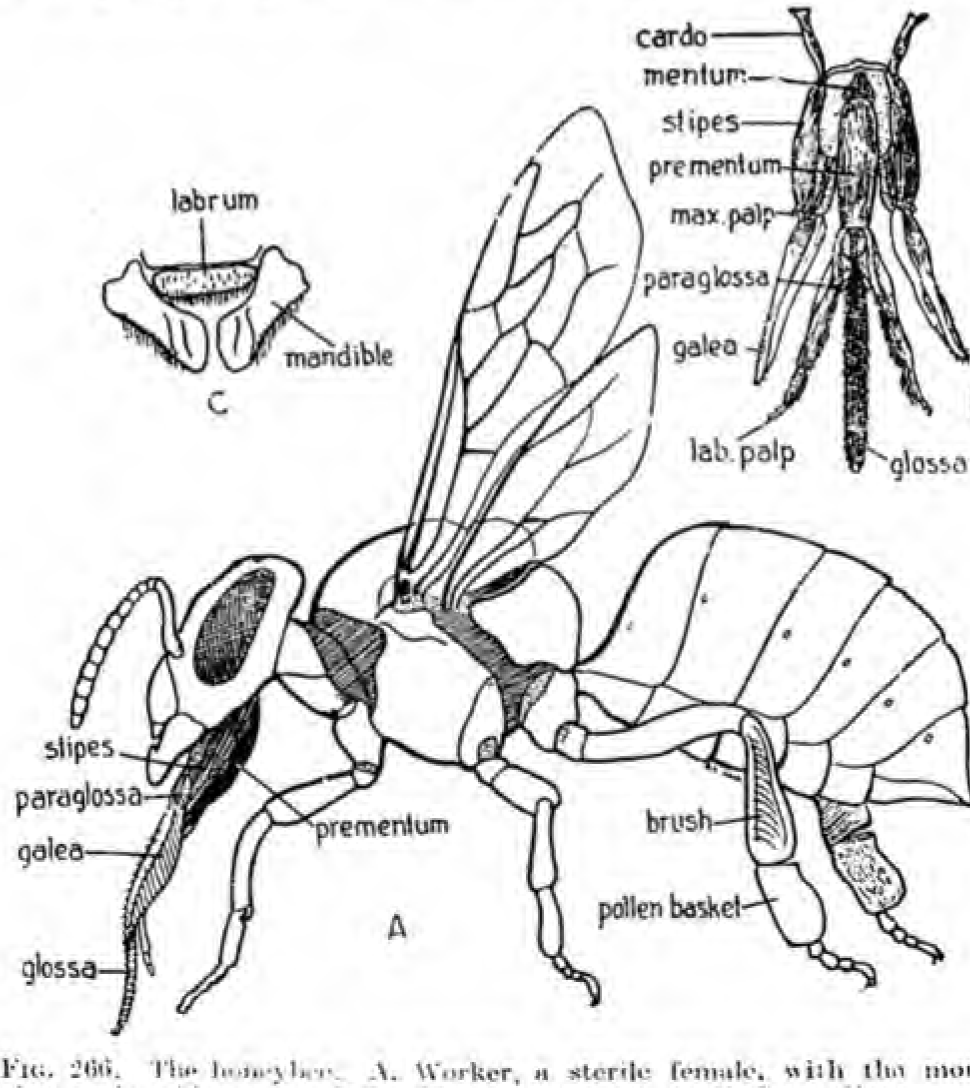


FIG. 266. The honeybee. A. Worker, a sterile female, with the mouthparts pushed out, in side view. B-C. Mouthparts. (*A & B from Hermann Weber: Grundriss der Insektenkunde, Gustav Fischer, Jena*).

The mouthparts are modified for gathering pollen and nectar. The mandibles are toothless and are used in working the wax into the walls for the cells of comb. The maxillae and labium are modified. The maxillary and labial palps form a sucking tube for the nectar. The sugars present in the nectar are acted on by enzymes in the stomach and

changed to ***dextrose*** and ***levulose.*** This liquid is regurgitated in a cell and further worked up in the mouth of bees that stay in it. The excess of water is evaporated by fanning with the wings. The final product is ***honey*** which is now sealed in the cell. When fresh, honey is colourless and contains about 17% of water and 78% sugars, with small amounts of minerals, enzymes, etc.

FIG. 267. *Apis dorsata*, the giant wild rock bee, in flight. Note the pollen brush and basket on the hindlegs.

The body of a bee is covered by branched or plumose hairs, that serve to brush off the pollen. The hairs on the hind legs are specially long and form the ***pollen brush.*** The hindtarsus is modified as a ***pollen basket.*** The pollen is rolled into pollen balls with honey and saliva These are used as ***bee-bread*** for feeding the young.

Bees are one of the most useful insects. In addition to supplying honey, which is a wholesome food, and the useful bees' wax, the bees help man indirectly also. They pollinate flowers and thus increase the yield of fruits and other crops.

Bees have numerous enemies: man, monkeys, bears, birds, ants and numerous other insects rob them of their store of honey. The wax-moth

caterpillar tunnels through the honey combs. They are also parasitized by numerous insects. Bees are subject to epidemic diseases.

Order LEPIDOPTERA

Butterfly

The Lepidoptera, which comprise the butterflies and moths, are large insects with two pairs of wings. The body and wings are covered by minute scales (Fig. 268 B) which form colour patterns. Mouthparts

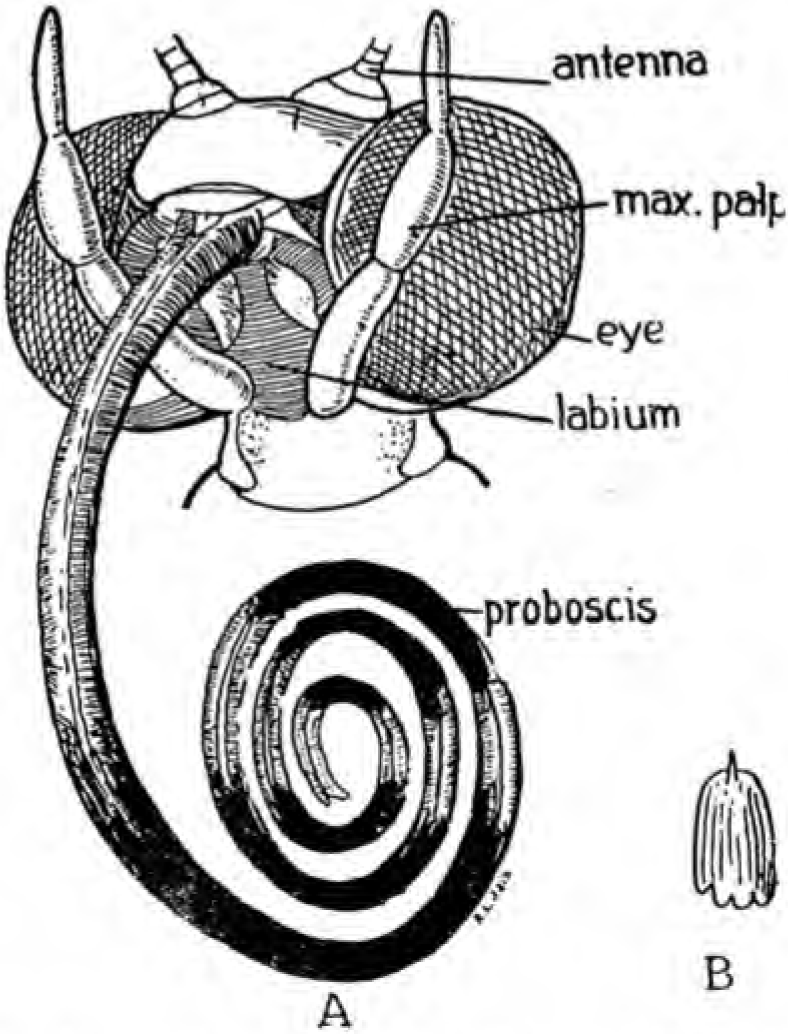


FIG. 268. A. Head of the butterfly in front view, with the proboscis partly unrolled. (*From Hermann Weber: Grundriss der Insektenkunde, Gustav Fischer, Jena*). B. A scale from the wing of a butterfly.

(Fig. 268 A) are modified into a ***proboscis***, adapted for sipping liquids and coiled under the head when not in use. The mandibles are obsolete. Development includes great metamorphosis with a resting stage. There are thousands of species of butterflies. *Danaus chrysippus* or milkweed butterfly,

is very common all over India and extends to Arabia, S. Europe, China, Malaya and East Indies. It loves sunshine and open fields and gardens full of flowers, which it visits for nectar (*See Frontispiece*).

All butterflies pass through 1. egg, 2. larval, 3. pupal and 4. imaginal stages in their life-history (pl. iii). The females of *Danaus* butterfly lay cylindrical cream-coloured eggs on the leaves of the common milk-weeds like *Calotropis*, *Daemia*, etc. The ***incubation*** or the embryonic development is completed in three or four days. A butterfly does not hatch from these eggs, but a small worm-like larva or ***caterpillar*** comes out. It is about 2 mm long and pale yellow, has three jointed legs, behind the head and five leg-like fleshy stumps called ***prolegs*** on the abdomen. It devours the empty egg-shell out of which it has come and then proceeds to feed on the leaf. It has well developed mandibles, with which it bites and chews pieces of leaf. It steadily grows and when it is 5 mm long it moults or casts off the skin. After the first moult, the caterpillar rapidly gains in size and after a few days moults a second time. After four moults the caterpillar is full grown, banded yellow and black, with three pairs of reddish fleshy filaments on the back.

It now ceases feeding and wanders about in search of a suitable place to rest. It forms a thin silken pad on the under surface of a leaf or a branch. It hangs head downwards from this pad by the last pair of prolegs. The next day it moults for the last time and an oval, shiny, waxy-white ***pupa*** results. It is ornamented with beautiful golden spots. There is no trace of legs, mouth or any indication of life. This is a "resting" stage, during which profound changes are taking place inside. Some of the larval organs disappear and adult organs like the wings, proboscis, etc. develop. After about a week the apparently lifeless pupa bursts and the gorgaous butterfly emerges. First its wings are soft and crumpled and the butterfly hangs with the wings down. Soon the wings expand and harden and an hour later the butterfly flies off to sip nectar from flowers. The whole life-cycle occupies about a month. The butterfly undergoes complete metamorphosis : the young is wholly unlike the adult. The development of the butterfly is thus different from that of the cockroach. Butterflies are ***holometabolic*** insects or insects which undergo complete metamorphosis. The cockroach undergoes incomplete metamorphosis and is therefore a ***heterometabola***.

Butterflies cannot feed on solid food. They visit flowers and sip the sweet nectar from them. While doing so, they accidentally pollinate the flowers also. Apart from being wonderful objects of exquisite colour and beauty, they do considerable good by effecting cross-pollination of flowers.

Silk moth

Most moths differ from butterflies in having stout bodies, branched or plumed antennae, nocturnal habits and in other characters. Their life-histories are however essentially similar to those of the butterfly. Many of them spin a case or ***cocoon*** of silken threads in which they pupate. The silk is the hardened saliva of the caterpillar.

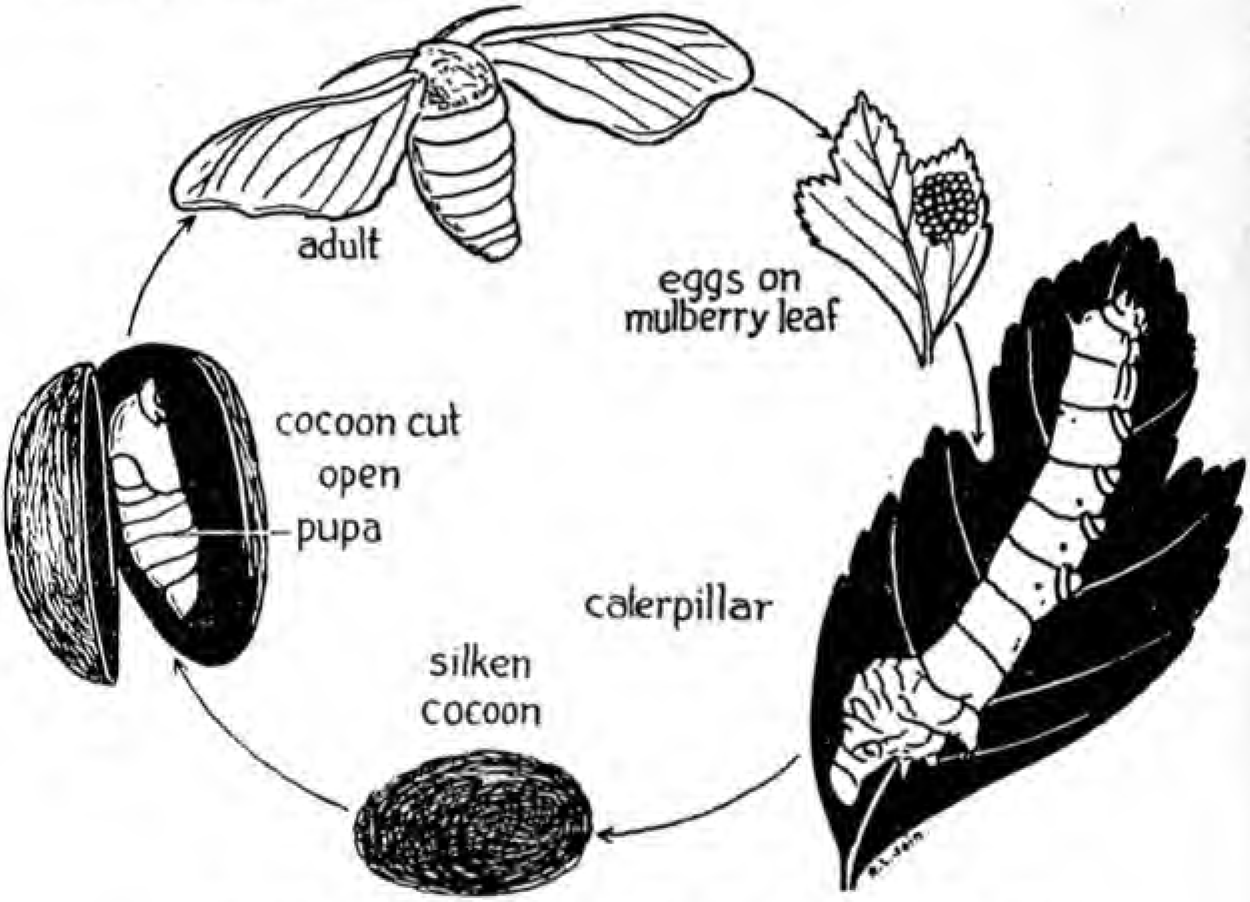


FIG. 269. *Bombyx mori*, the mulberry silk moth. Life-history.

There are many silk-producing moths but *Bombyx mori* or the mulberry silk moth has been domesticated for several centuries. The Chinese were the first to discover the manufacture of silk, which was kept a closely guarded secret. Some monks smuggled the secret out of China. Even to this day China and Japan are the only countries where ***sericulture*** or silk growing is extensively practised.

The female moth lays about 400 eggs. The caterpillar eats the mulberry leaves and when fullgrown spins the cocoons, taking three days to complete. Then it pupates inside. The adult is not allowed to emerge, because the moth secretes an alkaline liquid to soften the silk at one end of the cocoon to make an exit. This breaks the silken threads into small

bits. The cocoons are therefore plunged into hot water, which kills the pupa and also facilitates unwinding of the threads. A few cocoons are

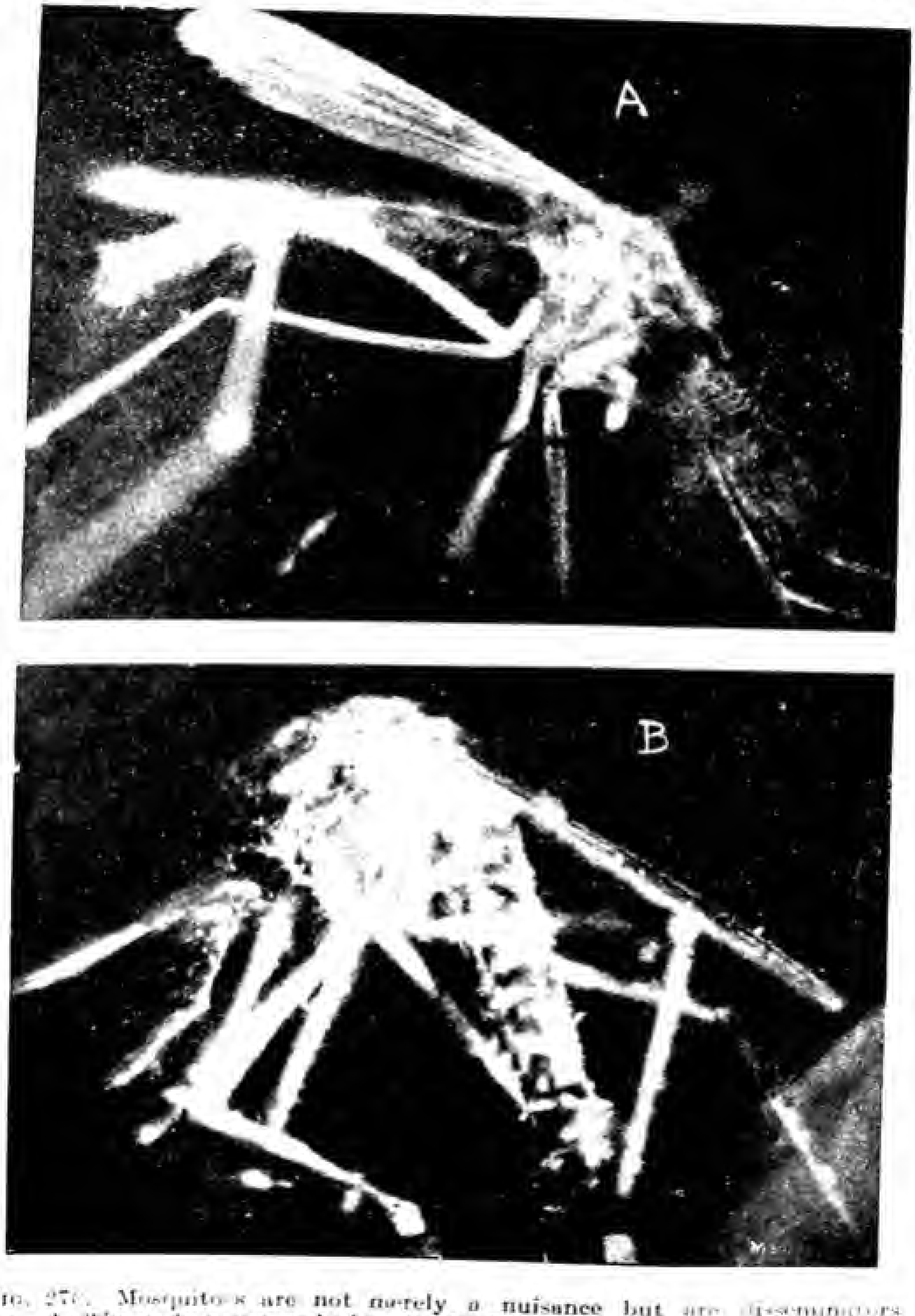


FIG. 276. Mosquitoes are not merely a nuisance but are disseminators of diseases. A. The male never sucks blood. B. The female alone is capable of sucking blood and is the menace of man.

preserved as "seed" for the next crop. About 25,000 cocoons yield a pound of silk. The "silk worm" is subject to a serious and fatal disease called ***pebrine***, which is transmitted through eggs from a parent. It is also attacked by insect parasites.

Order DIPTERA

Mosquito

Mosquitoes are small soft-bodied insects with only one pair of wings: the hind pair is reduced to knobbed stalks called ***halteres*** or ***balancers***. The body and wings are sparsely covered by ***scales***. The antennae are slender and long and in the male clothed with long hairs. The mouthparts are modified into a long piercing and sucking proboscis (Figs. 271, 274).

Mosquitoes are common in damp, moist or marshy localities and are specially abundant in the tropics. They lay eggs in water and their larvae and pupae are aquatic.

Mosquitoes belong to the family Culicidae. There are two classes of mosquitoes: 1. Culicine and 2 Anopheline. The anopheline mosquitoes are also called "malaria" mosquitoes. They are distinguished from the culicine forms by 1. their spotted wings, 2. the elongated palpi of the female nearly as long as the proboscis, 3. the last two segments of the palpi are swollen in the male and 4. anopheline mosquitoes "sit" slanting, with the head closer to the surface than the tip of abdomen, while the culicine mosquitoes rest with the body parallel to the surface.

COMPARISON BETWEEN CULICINE AND ANOPHELINE MOSQUITOES

Culicine	*Anopheline*
1. Eggs are placed vertically on the surface of water to form egg rafts.	Eggs are laid singly on the surface and each provided with a float.
2. Larvae are bottom feeders.	Larvae are surface feeders.
3. Larvae hang from the water surface head downwards at an angle.	Larvae rest with the body parallel to the water surface.
4. Larya without branched hairs.	Larva suspended from the surface film by branched hairs.
5. Larva has a respiratory tube on the 8th segment.	Larva has a respiratory pore dorsally on the 8th segment.
6. Palpi of adult female shorter than proboscis.	Palpi of adult female as long as or longer than proboscis.
7. Palpi of male long and pointed.	Palpi of male clubbed at the tip.
8. Wings generally not spotted.	Wings generally spotted with scales.

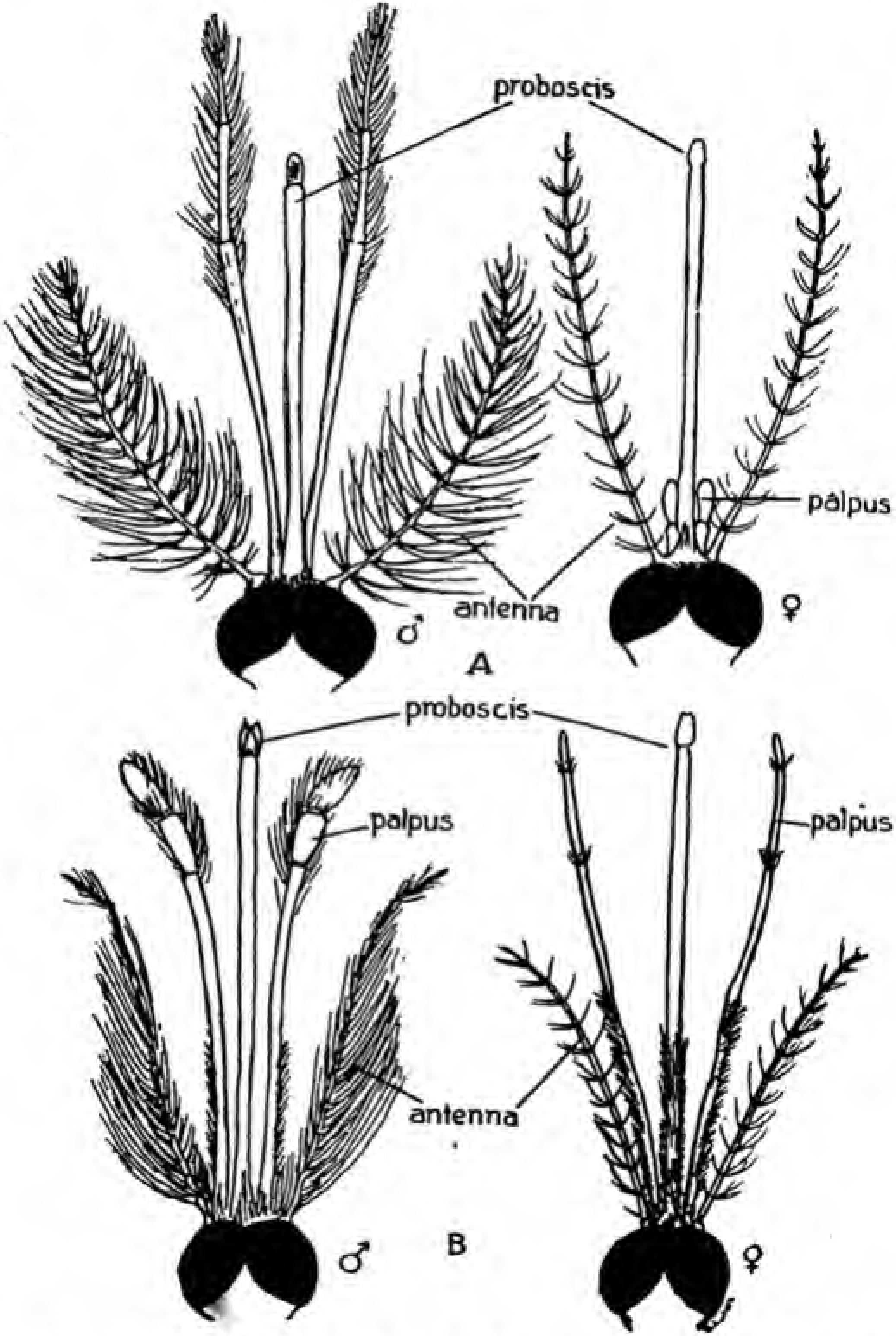


FIG. 271. Heads of mosquitoes, showing the antennae and mouthparts. A. Culicine mosquito. B. Anopheline mosquito.

9. Adult rests with the body parallel to the surface.	Adult rests with the body at an angle to the surface.

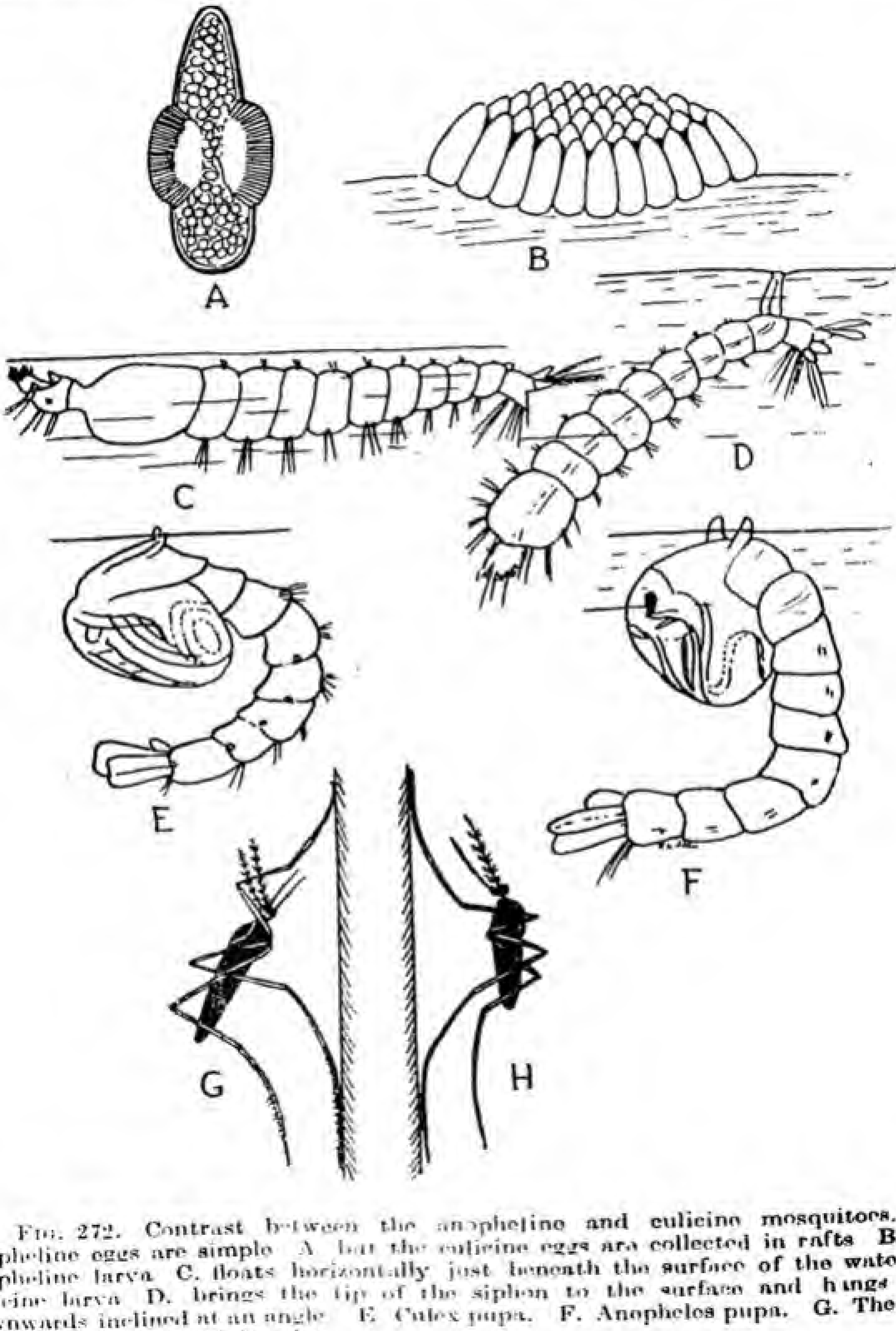


FIG. 272. Contrast between the anopheline and culicine mosquitoes. The anopheline eggs are simple A but the culicine eggs are collected in rafts B. The anopheline larva C. floats horizontally just beneath the surface of the water, the culicine larva D. brings the tip of the siphon to the surface and hangs head downwards inclined at an angle E. Culex pupa. F. Anopheles pupa. G. The adult anopheles. H. The adult culex.

The common ants of India include the red ant *Formica*, the large carpenter ant *Camponotus* and the harvesting ant *Holcomyrmex*. The spinning *Oecophylla* is a formidable species. It webs the leaves especially of mango trees, into a nest. The larvae secrete the silken thread

FIG. 264. Ants domesticated animals and also showed high degree of parental care long before there was any man on the earth. Here an ant is shown extracting the sweet honey-dew from an aphid or "ant cow" that it has domesticated. Another ant is carrying an ant larva. (*Adopted and modified from Younge-Bateman*).

A batch of workers bring the edges of leaves together while another batch hold the larvae in their mouth (Fig. 262) and move them back and forth, expertly using them as a sort of living thread ball.

Ants keep many pets. Several insects like beetles, crickets, wasps, flies, etc., are ***myrmecophilous*** and habitually inhabit the nests of ants. A small mosquito *Harpogomyia* waits for an ant. When one comes near, the mosquito imprisons the ant between its legs. The ant opens its jaws and gives out a drop of food for the mosquito

Honeybee

Honeybees are social insects. They build hives of wax combs and store up honey. They have been domesticated by man since long. The domesticated species in Europe and America is *Apis mellifica*. In India there are three species : 1. *Apis dorsata* the rock bee, 2. *Apis indica* the Indian bee and 3. *Apis florea* the little bee. *A. dorsata* is wild and constructs huge combs on overhanging rocks and inaccessible part of buildings or on trees. It is the largest bee and stores considerable

insects like aphids, cow-bugs, etc. (Figs. 263, 264) which secrete a sweet honey-dew highly prized by the ants. The aphids are protected by the ants, which drive away the enemies of aphidsi The ants also carry the aphids from their nests to the plants to feed, bring them back after "grazing", collect and store their eggs! The aphids are so completely dependent upon the ants that they cannot live without them. Some species of ants keep slaves. They raid the nests of other kinds of ants and carry off

FIG. 263. Ants domesticated animals long before man. Cowbugs (Membracids) are cared for by ants and give in return a sweet honeydew to their masters.

their larvae to their own nests. The workers which emerge are enslaved and made to do all the work for their masters, who indeed cannot even feed themselves. The slaves have to convey the food to them!

The larvae feed on minute organic particles in the water or on small Protozoa. The adult female punctures the skin and sucks the blood of

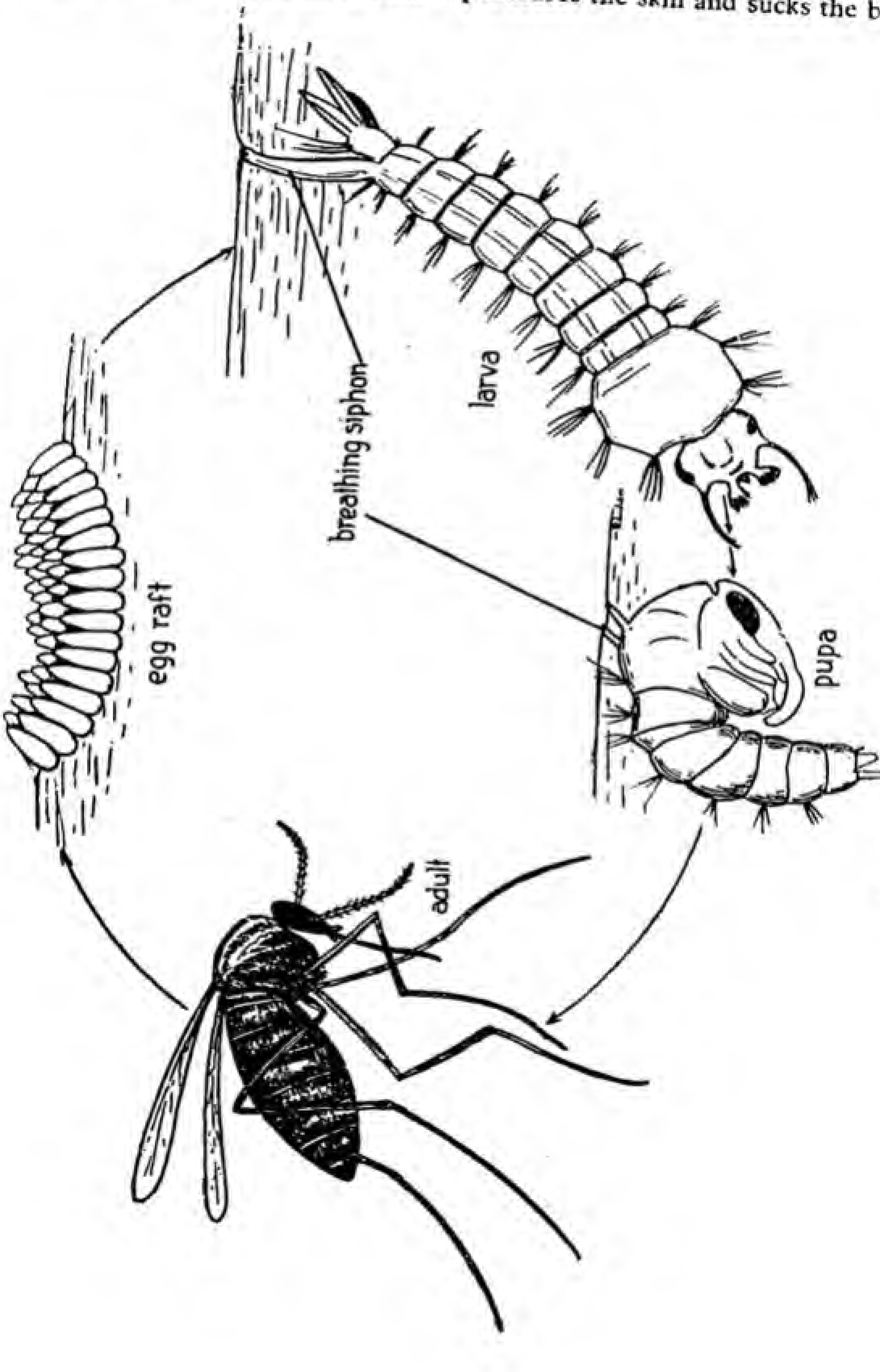


FIG. 273. Life-history of the mosquito.

various animals. The males are entirely harmless and incapable of sucking blood.

The mouthparts (Figs. 271, 274) comprise an elongated ***proboscis*** which is the modified labium. The labium is elongated into a half tube and contains the long needle-shaped labrum, mandibles, maxillae and hypoyharynx, the six ***piercing stylets.*** The palpi are used as tactile organs. The skin is punctured by the stylets, which are thrust into the puncture. The saliva is injected from the hypopharynx. The mixture of saliva and blood is sucked up by the tube formed by the labrum and labium.

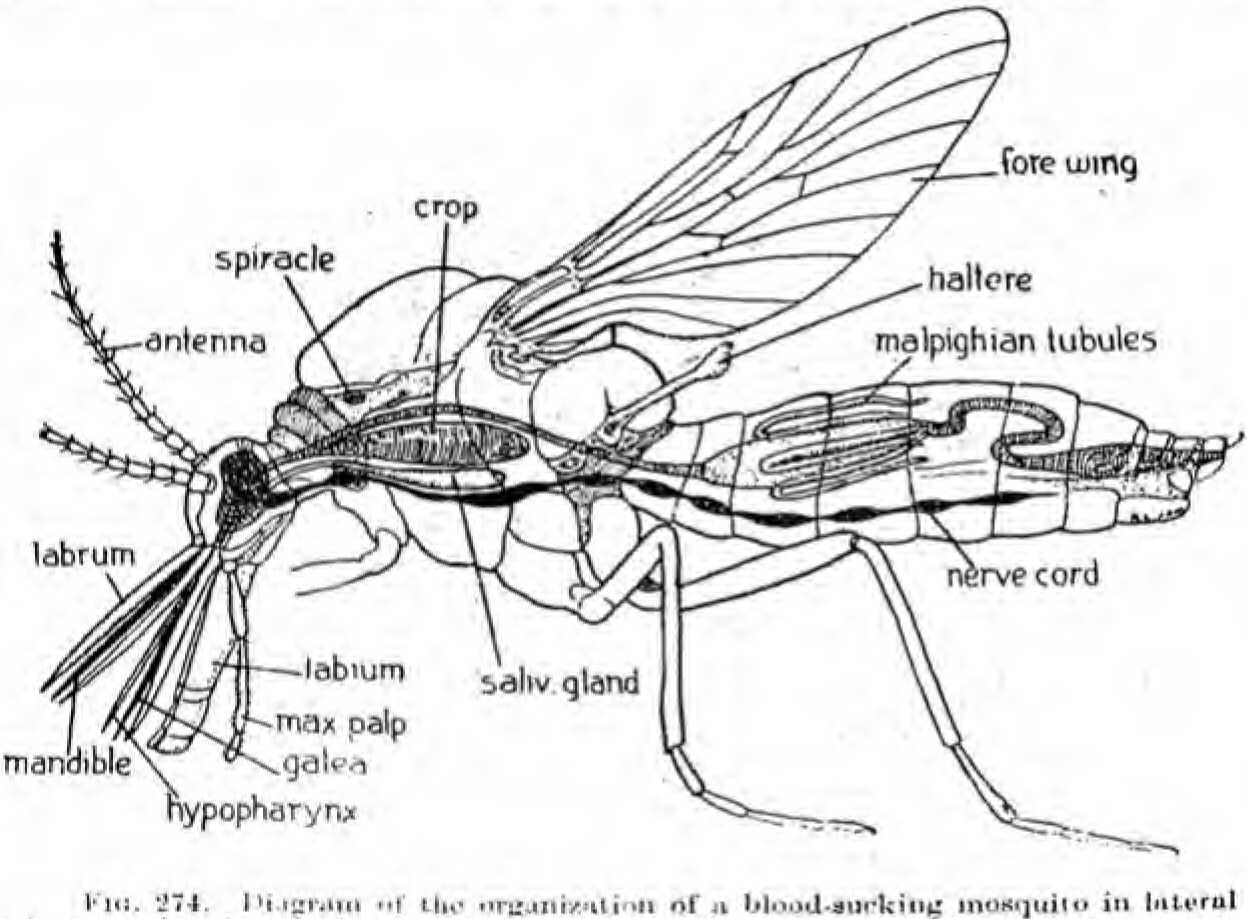


FIG. 274. Diagram of the organization of a blood-sucking mosquito in lateral view, showing the mouthparts, the digestive canal, salivary glands and nervous system. (*From Hermann Weber : Grundriss der Insektenkunde, Gustav Fisher, Jena*).

The mosquito (Fig. 273) lays eggs in water : culex eggs form rafts, with the egg vertical, the anopheles eggs float horizontally. The young larva hatches in about 2-3 days. The larva has no legs. The anopheles larva lies horizontally just beneath the surface of water. The culex larva hangs head downwards, with the respiratory tube touching surface of water. In about a fortnight the larvae are fully grown and pupate. The pupa is provided with two small breathing tubes. The adult emerges in two or three days.

Mosquitoes not only cause annoyance and pain by biting and sucking ›d but also transmit many diseases. Mosquito-borne diseases of man ude 1. malaria, 2. dengue, 3. filariasis, and 4. yellow fever. ıaria is transmitted by anopheline mosquitoes. The following species important malaria carriers: *Anopheles culicifacies*, *A. fluviatilis*, *A. ıimus*, *A. stephensi* and *A. sundaicus*.

Culex fatigans and other culicine mosquitoes transmit filariasis. :llow fever does not occur in India, but the carrier mosquito *Ades* ɡypti is found in this country.

Housefly

Houseflies (Fig. 275) are cosmopolitan insects that flourish wherever ıere is man, filth and unhygienic conditions. Next to ant they are the ıest known insects.

FIG. 275. *Musca nebulo*, the common housefly of India.

Houseflies differ from mosquitoes in having short antennae: there are only three segments, the third segment is the largest and bears a

hair-like ***arista***. Eyes are large. The mouthparts (Fig. 276) comprise a ***proboscis*** composed of labrum, hypopharynx and labium, supported by a membrane. The proboscis includes a ***rostrum*** at the base, a ***haustellum*** in the middle and a ***labella*** below. The labella is made of broad pads, which can be spread out on any moist surface. They are not adapted for piercing or puncturing skins but for lapping liquids from moist surfaces. Houseflies cannot therefore "bite".

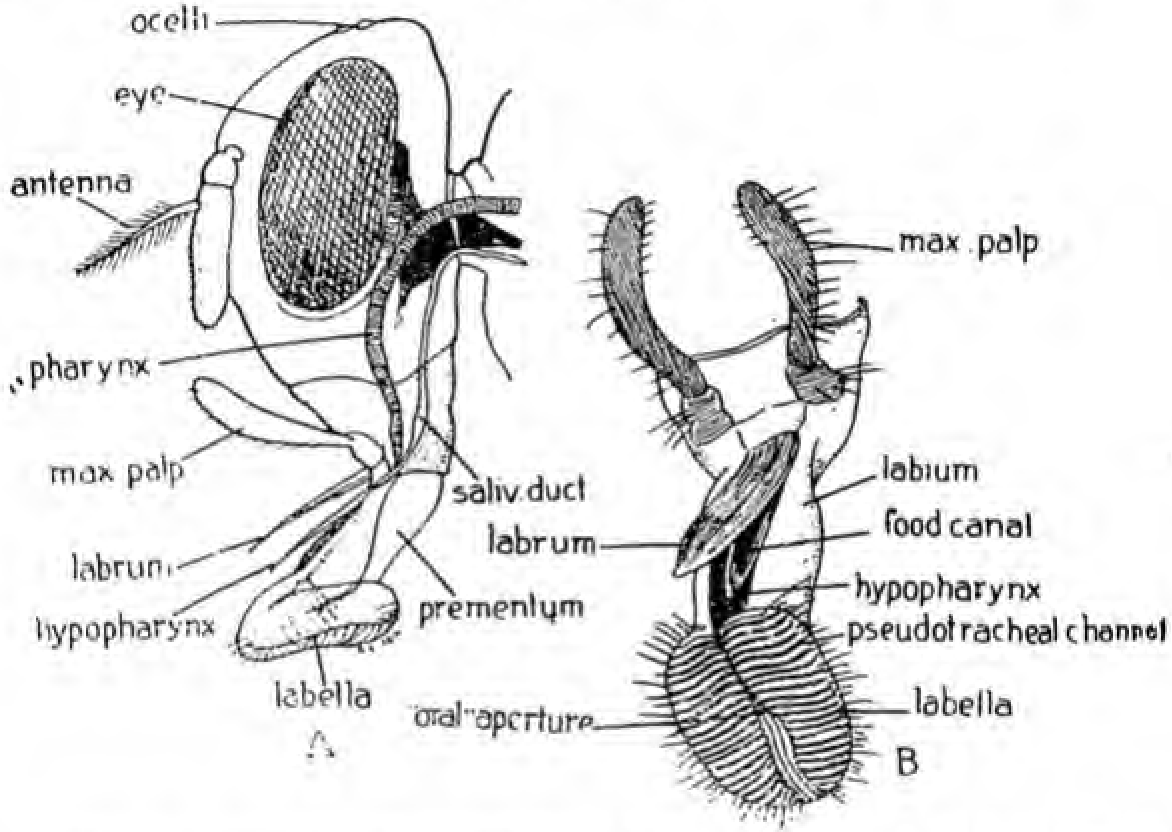


FIG. 276. The head and mouthparts of the housefly. A. The head in lateral view, with oesophagus, brain and mouthparts (*Adapted from Hermann Weber: Grundriss der Insektenkunde, Gustav Fischer, Jena*). B. Mouthparts tilted to show the sponging surface of the labella.

The eggs are deposited in farm yard manure, cow dung, garbage, human faeces and other decomposing organic matter. The eggs are small, elongate and pearly-white. Each female lays about 500 – 600 eggs. The eggs are already in an advanced state of development. In about 24 hours small, slender, creamy-white, headless and legless larvae called ***maggots*** hatch out. The maggots writhe and wriggle about among the debris on which they feed. In about a week they reach maturity. Then the maggots wriggle under the soil to pupate. The pupae are dark-brown and smooth. In about four or five days the adult flies emerge. Hundreds of generations develop in spring, summer and autumn but the number of flies diminish in winter.

Houseflies are very agile in their movements. They are also extremely pertinacious. They are attracted by warmth, dampness, and light. Odours from fruit, food material and any decomposing matter attract them powerfully. Though they breed in filth and feed on all sorts of substances, houseflies spend a considerable part of their time in toilet: they brush their wings, abdomen and eyes by the legs and lick the legs clean.

The housefly has numerous enemies: spiders, insects, lizards and birds hunt flies systematically. It also suffers from diseases due to bacteria and fungi. Owing to the habit of passing directly from filth to human food, the housefly is a menace to public health. It transports bacteria and other pathogenic organisms to the food. It plays an important part in the dissemination of cholera, typhoid, dysentery, infantile diarrhoea, etc.

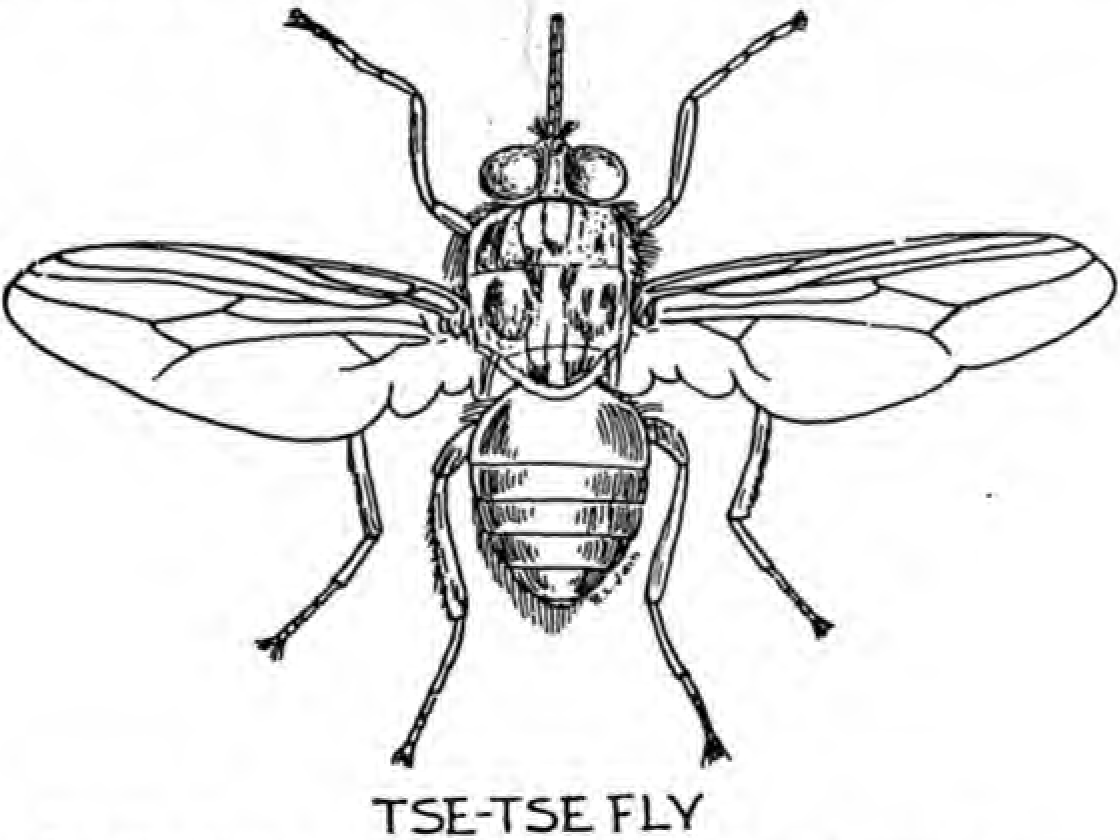


FIG. 277. *Glossina palpalis.* Female of the tse-tse fly transmits *Trypanosoma gambiense*, the causal agent of the dreaded sleeping sickness from man to man by means of its piercing mouthparts.

There are several species of houseflies: *Musca domestica* is cosmopolitan; *M. vicina* and *M. nebulo* (Fig. 275) are the common houseflies of India; *M. pattoni* is also abundant in certain parts of India. Among the other muscoid flies may be listed: *Glossina* the tse-tse fly (Fig. 277), *Stomoxys* the stablefly,

Haematobia the hornfly and *Gasterophilus* the nose botfly. These are blood-sucking flies and are responsible for causing various diseases. *Glossina* transmits *Trypanosoma* of the sleeping-sickness. The nose botfly lays eggs on the lips of the horse—the larvae pass into the stomach and become fixed.

Order SIPHONOPTERA

Fleas

Fleas (Fig. 275) are minute, compressed, hard-bodied, wingless, jumping insects, with piercing and sucking mouthparts. They are intermittent blood-sucking ectoparasites mostly on mammals like rats, squirrels, cats, dogs, and man.

The eggs are scattered all over the place where the host lives. The worm-like larvae are non-parasitic, with biting mouthparts and develop on organic debris. When mature, they pupate in small cocoons.

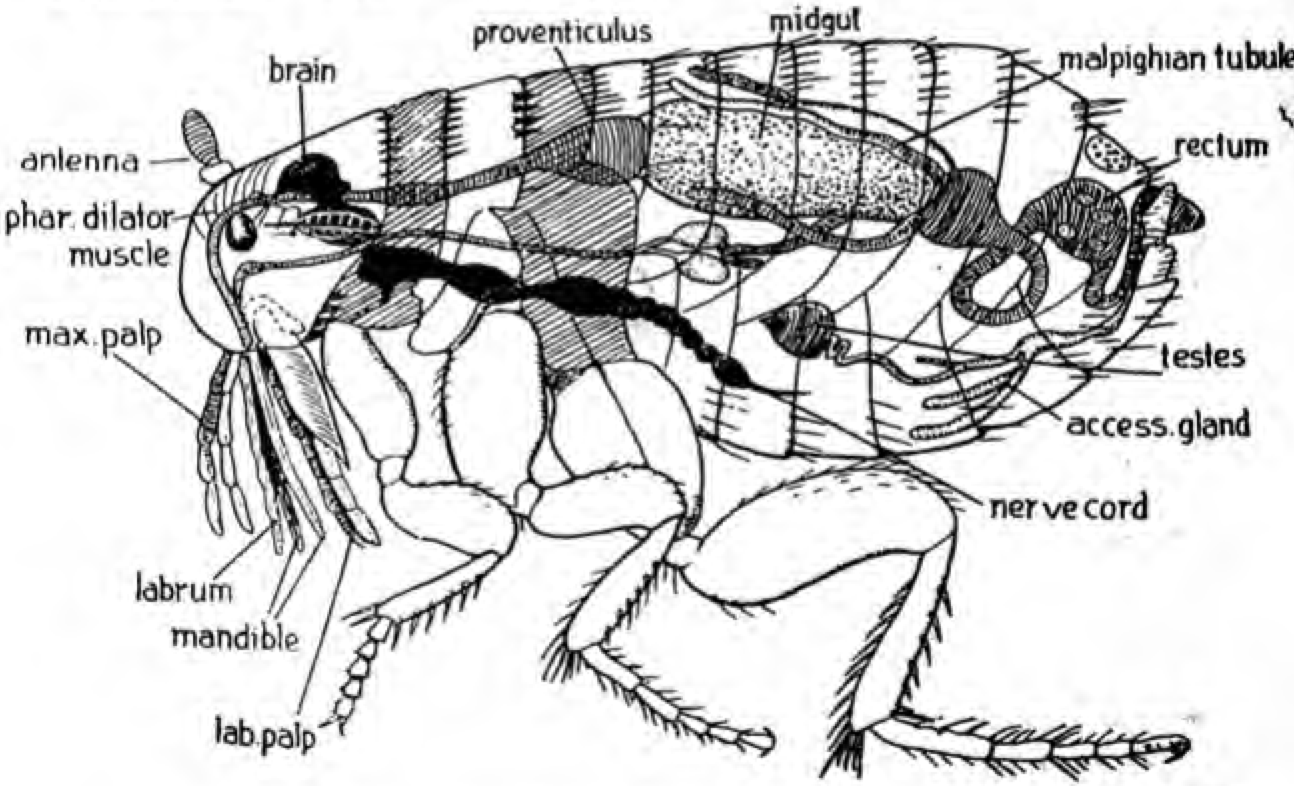


FIG. 278. Diagram of the organization of the rat flea in lateral view, showing the mouthparts, the alimentary canal, the nerve cord and reproductive organs. (*From Hermann Weber: Grundriss der Insektenkunde, Gustav Fischer, Jena*).

Fleas normally infest cats, rats and dogs but will readily attack man. Fleas cause intense irritation and pain by their bite. They transmit the bubonic plague from rat to rat or from rat to man. Endemic typhus is also transmitted by flea bite. The common fleas include 1. *Pulex irritans* the

human flea found on man, dog, cat, rat and poultry all over the world; 2. *Xenopsylla cheapis* the rat flea which transmits plague; and 3. *Ctenocephalides* cat and dog fleas.

RESUMÉ

1. From the stand-point of man insects are either neutral, beneficial, useful or injurious

2. The vast majority of insects are of neutral value. The locusts, crickets, termites, lice, flies, mosquitoes and bugs are harmful. The lac insect, honeybee and silk insect are useful.

3. The injurious insects destroy our crops, spoil our food, clothing, furniture, etc , act as vectors for various diseases of man and his domestic animals or are enemies of useful insects.

4. Locusts are grasshoppers that periodically become gregarious and migrate in swarms. They lay waste thousands of acres of crop.

5. Termites are subterranean social insects with a complicated secular government ruled by the queen termite, guarded by soldiers and maintained by workers.

6. Lice are ectoparasites of man and other animals. They suck blood and transmit fatal diseases.

7. The bedbug is a loathesome blood-sucking parasite of man, found in old insanitary houses, prisons, hostels, railway carriages, etc. It is active mostly at night.

8. The lac insect has been known from time immemorial. Lac is a resinous secretion of the insect and is employed in the manufacture of various products

9. Ants are social insects that are found all over the world. They are remarkable for their industry and high development of brain. They build roads, bridges and cities, cultivate plants, keep slaves, domesticate animals and rear pests.

10. The honey bees are social insects that build hives of wax, in which they store honey and pollen. They not only yield honey and bees' wax but also increase our crop by pollinating flowers.

11. Butterflies undergo complete metamorphosis. Larvae that hatch from the eggs feed, moult several times, pupate and emerge as adults.

12. Silk has been manufactured in China from very early times. It is produced by the silk moth caterpillar that feeds on mulberry leaves and spins a cocoon before pupating.

13. Mosquitoes are blood-sucking flies that breed in water. They are of two kinds: anopheline and culicine. Only the females suck blood and the males are harmless. Anophelines transmit malaria; the culicines transmit yellow fever, elephantiasis and other diseases.

14. Houseflies flourish in filth and garbage. They cannot suck blood but contaminate food and thus transmit cholera, dysentry, typhoid, etc

15. Fleas are minute jumping insects that breed in filth. They bite and suck blood normally of rat, cat, dog, etc. Sometimes they attack man also. The rat flea is a vector of the bubonic plague.

CHAPTER XVI

ECHINODERMATA

Echinodermata. The ECHINODERMS (*echinus*=spine, *derma*=skin), are wholly marine animals that have calcareous spines and plates in their body wall. They are superficially radially symmetrical. They possess a vascular system containing water. They include the starfishes, brittle stars, basket stars, sea urchins, cake urchins, sand dollars, sea cucumber, holothurians, sea lilies and feather stars

Characters. —

1. Multicellular, triploblastic, marine with well developed coelom. No head.
2. Primarily bilaterally symmetrical but superficially radially symmetrical, often bearing pentamerous arms or rays.
3. Exoskeleton of calcareous plates and spines.
4. Alimentary canal complete, anus sometimes absent.
5. Water vascular system that subserves locomotory and respiratory functions. Coelom ciliated.
6. Sexes separate.
7. Development with metamorphosis. Larva ciliated, bilaterally symmetrical, free-swimming, fundamentally like the trochophore-tornaria type.

Classification.—

Phylum ECHINODERMATA. Triploblastic, coelomate. Exoskeleton of calcareous spines. Water vascular system.

Subphylum I. PELMATOZOA. Fixed by flexible stalk at some period of life. Viscera in a cup-shaped plated calyx.

Class 1. CYSTOIDEA. Extinct.

Class 2. BLASTOIDEA. Extinct.

Class 3 CRINOIDEA. Example : *Antedon* sea lily.

Subphylum II. ASTEROZOA. Stemless. Body depressed, pentagonal or stellate. Mouth and tube feet on the lower side.

Class 1. ASTEROIDEA. Arms hollow. Anus and madreporite dorsal. Tube feet with suckers. Examples : *Asterina*, *Asterias*, *Solaster*, *Pentagonaster* starfishes.

Class 2. OPHIUROIDEA. Arms solid. No anus. Madreporite actinal. Tube feet without suckers. Examples : *Ophiothrix*, *Ophiura*, *Ophiomyxa* brittle stars.

Subphylum III. ECHINOZOA. Stemless, armless. Globose, discoidal or Vermiform.

Class 1. ECHINOIDEA. Body plated. Spines movable. Tube feet actinal and dorsal. Examples : *Echinus* sea urchin, *Spatangus* heart urchin.

Class 2. HOLOTHUROIDEA. Body wall leathery with microscopic calcareous spicules. Vermiform. Examples : *Holothuria*, *Cucumaria* sea cucumber, *Synapta*.

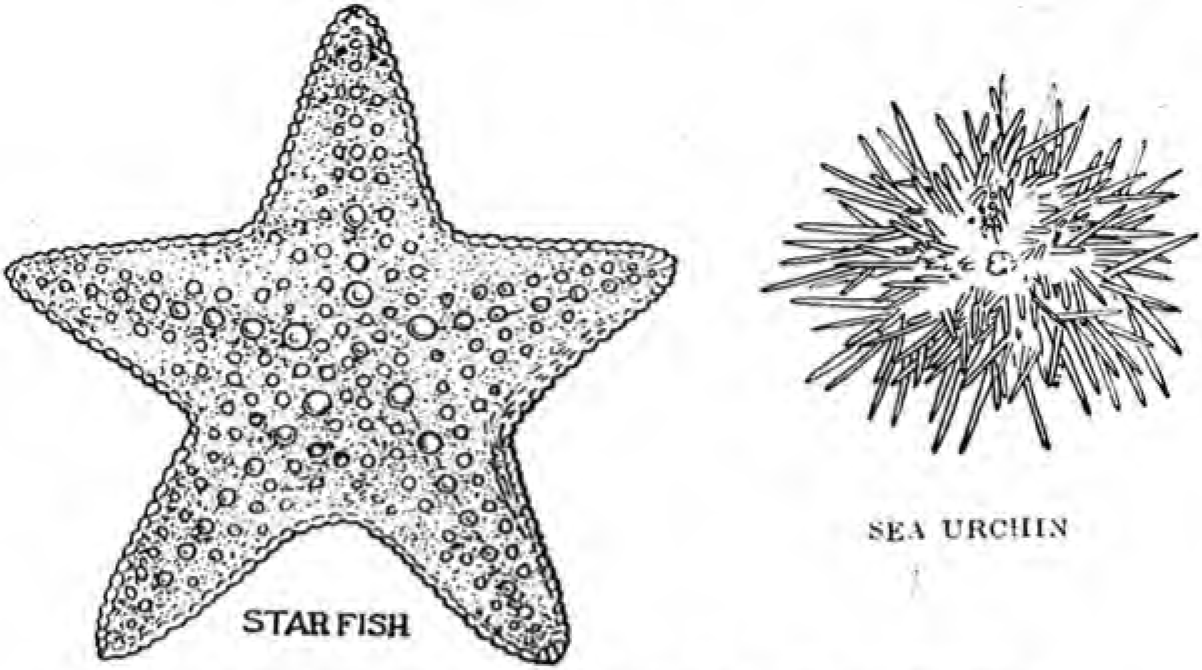


FIG. 279. Class Asteroidea : Starfish. Class Echinoidea : Sea urchin.

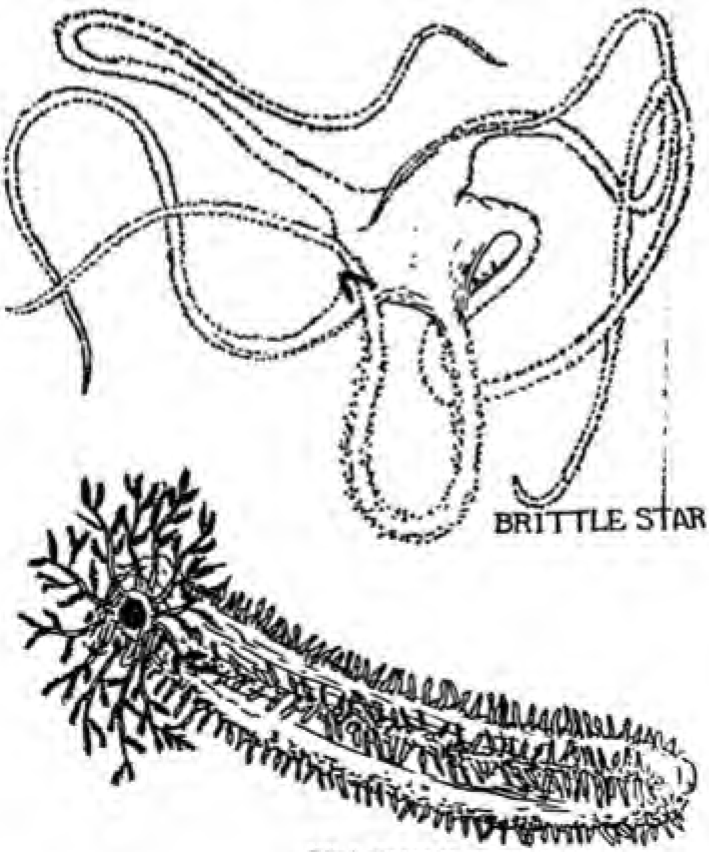


FIG. 280. Class Ophiuroidea ; Brittle star. Class Holothuroidea : sea cucumber.

Relation to man.— The starfishes constitute a serious menace to the oyster industry. The bivalve molluscs form the food of starfishes : a single starfish destroys as many as 20 clams within six days. The sea urchins are eaten in Italy, China and West Indies. The empty sea urchins, cleaned and filled with lead, serve as beautiful paper weights. The dried Holothurians are the ***trepang*** of Chinese dinner table ; trepang is made into soups.

ASTEROIDEA

The ASTEROIDEA or starfishes are depressed Echinoderms that are pentangular or have the conventional star shape, consisting of a central disc and five or more rays or arms.

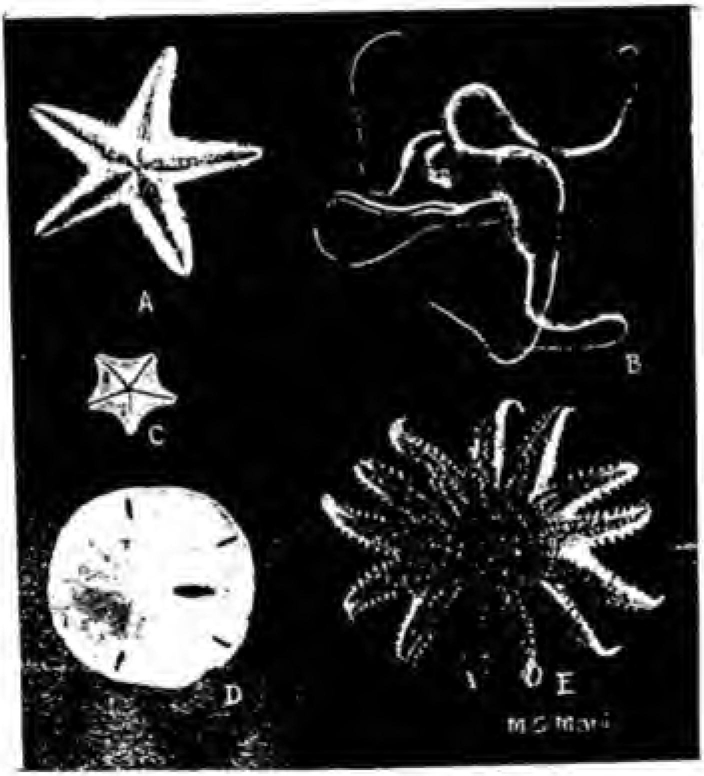


FIG. 281. Types of Echinodermata. A. ***Asterias.*** B. ***Ophiomyxa.*** C. *Asterina.* D. *Echinorchinus,* E. *Solaster.* (*Original photograph of specimens in the Zoology Museum, St. John's College, Agra*)

Classification.—

Order 1 PHANEROZONIA. Marginal plates large. Tube feet in two rows in each ambulacral groove. Examples : *Asterina* (Fig. 281) ***Astropecten.***

Order 2. CRYPTOZONIA. Marginal plates small. Tube feet usually in four rows in each ambulacral groove. Examples : *Solaster* **(Fig. 281),** *Arterias* (Fig. 281), *Echinaster.*

ASTERIAS

Bionomics.—Starfishes occur in all oceans and at all depths. They are however especially more abundant on rocky than on sandy shores. They remain quiet during the daytime under stones.

External features.—The body of starfish consists of a central ***disc*** from which arise five ***arms*** or rays. The upper or ***adoral*** (***aboral***) surface is covered by ***spines***. Numerous minute ***pedicellariae*** occur around the bases of the spines. The pedicellaria is a calcareous rod with two movable jaw-like processes above. It serves for cleaning the surface and for conveying the food particles towards the mouth. Irregular small projections of flesh through dermal pores between the pedicellariae are called ***dermobranchiae***. These function as gills. Amoeboid cells in the dermobranchiae eject waste matter to the outside. The ***anus*** lies close to the centre of the disc on the aboral surface. In one of the interradial lines on the aboral side is the ***madreporite***, a characteristic sieve-like porous plate leading into the water vascular system. The ***actinostome*** or the mouth opens in the centre of the disc on the ***actinal*** or ***oral*** surface, i. e. the lower side of the starfish The mouth is surrounded by a ***peristomal*** membrane. An ***ambulacral groove*** extends along the middle of each arm from the mouth to its tip. The groove is bounded above by a series of ***ambulacral ossicles*** arranged like a roof. The groove is filled with numerous ***tube feet***. At the tip of the arms are the ***ocular spots***. The arm opposite the madreporite is the ***anterior arm***. This and the two adjacent arms constitute the ***trivium***. The remaining two arms between which the madreporite is located comprise the ***bivium***. The skin is reinforced by mesodermal calcareous plates or ***ossicles***, that bear on the dorsal surface a number of short stout ***spines***. The outer surface of the body is covered by ciliated epithelium. Beneath the epithelium is a network of nerve fibrils and a two-layered mesoderm, with the ossicles originating from the outer layer.

Internal structure.—The arrangement of the internal organs is mostly pentamerous. There is a well developed alimentary canal and a characteristic system of water vascular tubes.

Digestive system.—The ***actinostome*** or the mouth leads into a short ***oesophagus***. Above the oesophagus is a wide five-lobed ***cardiac stomach***. Each lobe of the stomach is situated opposite one of the arms. The stomach is capable of great distension and can be everted through the mouth. ***Cardiac stomach*** communicates with the ***pyloric***

stomach, that leads into a short ***intestine.*** The pyloric stomach is pentagonal and is produced into the arms as five ***pyloric caeca.*** The caeca bifurcate at the base of the arm and each stem gives off branches laterally. The branches end in small pouches. The walls of the caeca are glandular. Paired ***intestinal caeca,*** each with numerous short irregular branches, lie interradially within the disc. The intestine then ascends to end in the anus on the adoral surface.

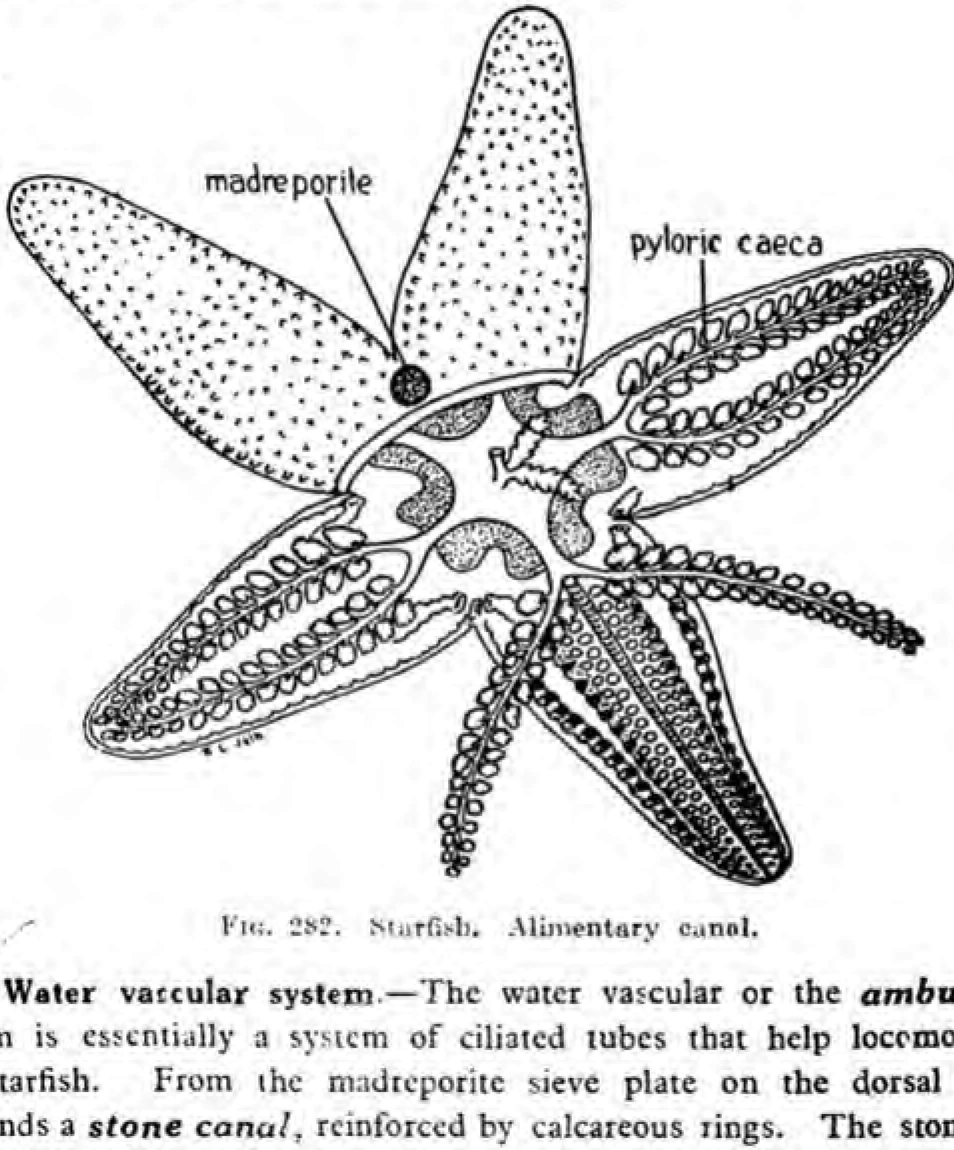


FIG. 282. Starfish. Alimentary canal.

Water vaccular system.—The water vascular or the ***ambulacral*** system is essentially a system of ciliated tubes that help locomotion of the starfish. From the madreporite sieve plate on the dorsal surface descends a ***stone canal,*** reinforced by calcareous rings. The stone canal opens below into a ***ring canal*** surrounding the short oesophagus. Five radial ***ambulacral vessels*** in the ambulacral groove extend from the ring canal to the tip of each arm and end in unpaired ***olfactory tentacles.*** The radial vessel gives off several lateral vessels that open into the bases of the tube feet. Each tube foot has above a bladder-like ***ampulla*** within the cavity of the arm. It ends below in a ***sucker,*** Each foo is really a

muscular tube that is capable of being distended by water. Five pairs of ***Polian vesicles*** or bladder-like structures, are attached interradially to the ring canal. At the sides of the neck of the Polian vesicles is a pair of glandular ***Tiedemann's bodies.*** The Polian vesicles and Tiedemann's bodies supply a lymph-like fluid. The starfish extends an arm in the direction it wants to move. The tube feet are then thrust out and anchored down to the surface by means of the powerful suckers at their tips. The body is now hauled forward. The tube feet also serve in forcing open the

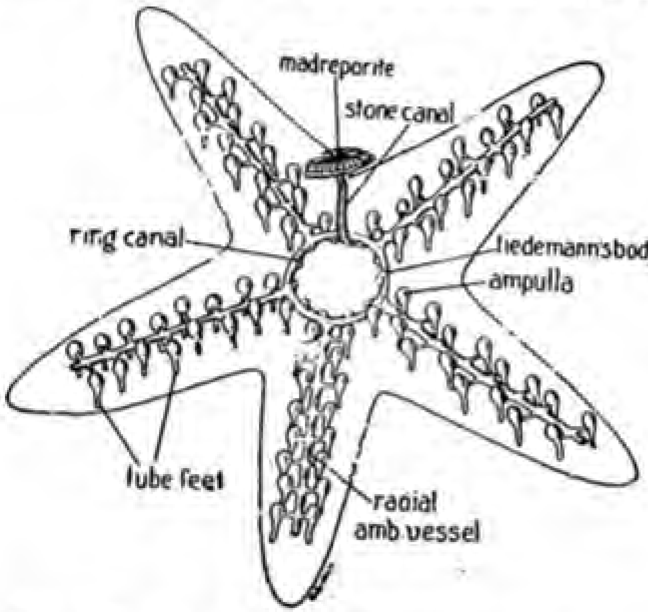


FIG. 283. Starfish. Water vascular system.

shell of Pelecypod molluscs that form the food of the starfish. The arms embrace the tightly closed shell, the tube feet are anchored on the surface and a powerful suction is applied. The valves slowly gape open. The starfish everts its stomach, folds it round the soft parts of the prey and retracts it into the body. Smaller shells are swallowed whole. The water vascular system is filled with sea water through the madreporite plate

There is no heart but there is usually a double system of vessels : one near the mouth and the other near the dorsal end.

Nervous system.—The nervous system comprises a ***nerve pentagon*** round the oesophagus, that gives off the ***radial nerves*** below the radial ambulacral vessel. Each radial nerve runs to the 'eye' at the tip of the arm. This constitutes the ***epidermal nervous system***. A ***deeper nervous system*** includes a double nerve pentagon. There is also an ***adoral nervous system*** near the roof of the arms.

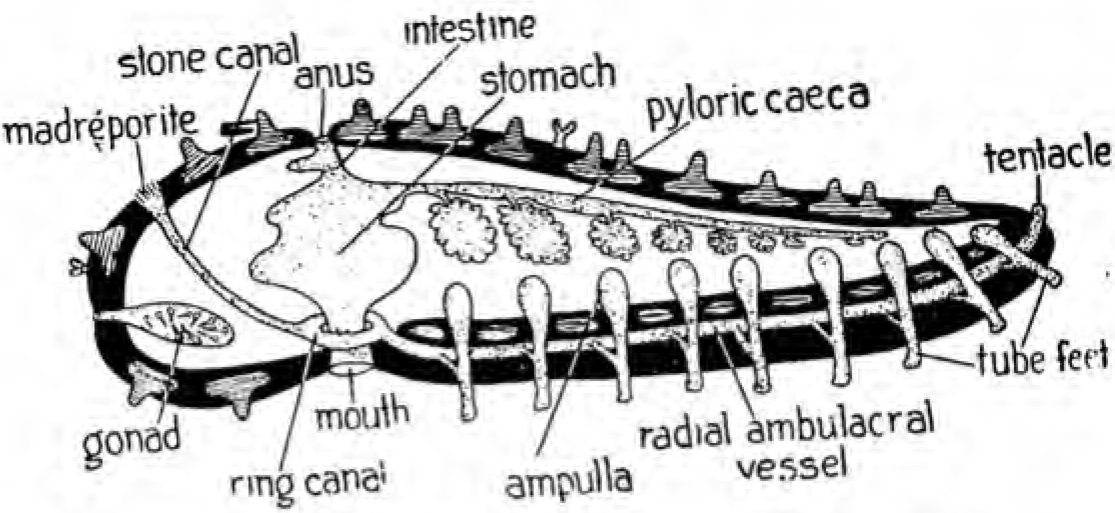


Fig. 284 Starfish. Longitudinal section of the disc and arm.

Reproductive system.—The strafish is ***unisexual.*** The gonads comprise paired masses of grape-bunch-like follicles in the interradial space of the disc. The ducts open to the outside on the dorsal surface by a number of perforations interradially close to the base of the arms.

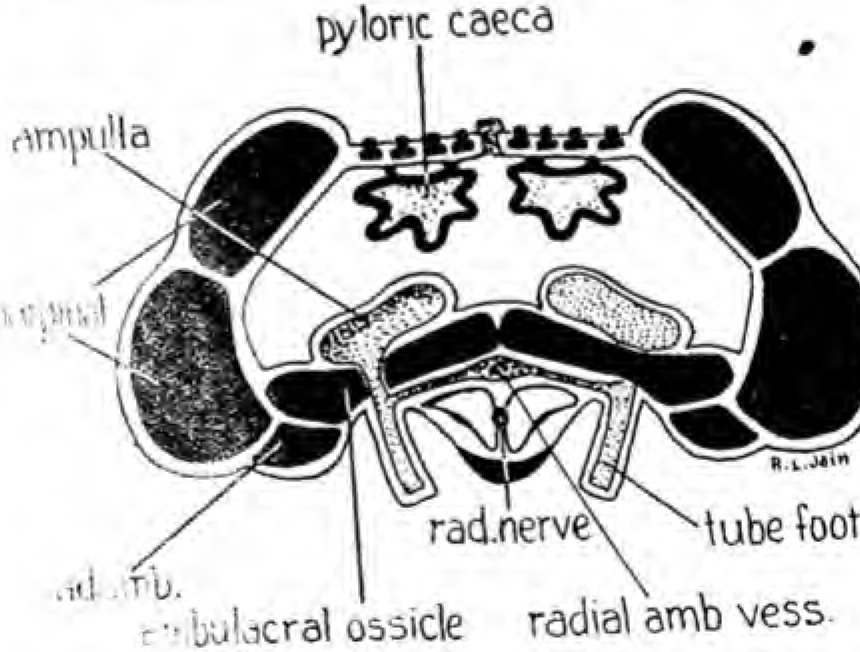


Fig. [illegible] Starfish. Transverse section through arm.

Regeneration.—The starfish has considerable powers of regenerating the last parts. As the arm contains almost all the important organs, a broken arm is capable not only of living but growing into a complete starfish. The arm first develops a small disc, from which four arms grow out later.

OPHIUROIDEA

OPHIUROIDEA or brittle stars possess well-defined central disc containing a simple digestive cavity which does not radiate into the slender rounded arms and has no anal opening. The reproductive organs are confined to the disc. The madreporite is always on the dorsal side of the disc.

Ophiuroids differ from typical starfishes in their cylindrical flexible arms, sharply separated from the central disc. The arms do not contain the diverticula of the alimentary canal or of the sexual organs. They serve as locomotor organs and are either plated or protected by coriaceous skin, in which are imbedded minute granules and scales. When plated, the covering consists typically of four rows of calcareous plates known as upper, lower and side ***arm plates.*** The lateral or the ***ambulacral plates*** usually

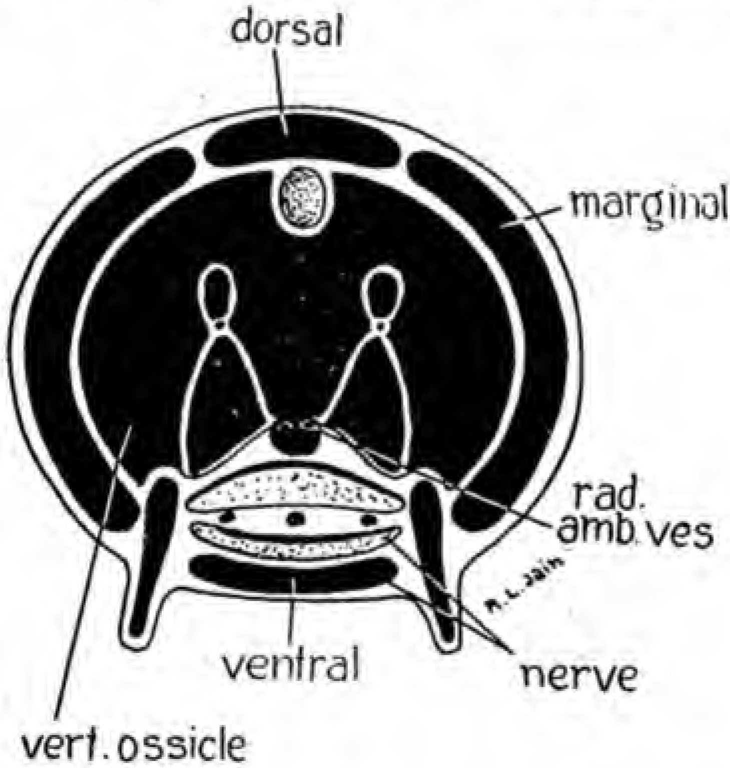


FIG. 286 Brittle star Transverse section through arm.

carry rows of mobile spines. The interior of the arms is occupied by the ***vertebral ossicles*** or ***arm bones,*** each of which is made up of two or four ambulacral pieces fused side by side. The arm bones are movably articulated with one another by means of ***bosses*** which project from the centres of both the surfaces, the interspace being filled up by muscle. The entire series is incised inferiorly along the middle for the ***radial ambulacral vessel,*** that gives off a pair of lateral branches in each arm

ossicle. These pierce the bone itself and supply the tube feet with water. There are no ampullae or suckers. The ***actinostome,*** in the centre of the underside of the disc, leads into a large sac-like ***stomach ;*** there is no intestine. The ducts of generative organs open into five pairs of folded pouches, one to each interbrachial area. These communicate to the exterior by means of the genital slits.

The integument is beset with calcareous plates on the upper surface of disc and interbrachial area on the ventral side. A large central plate, sometimes on the central part of the disc, together with five pairs of plates radiating out is called the ***radial shield.*** On the ventral side is a single large plate, ***mouth shield*** or ***scutum buccale,*** at the inner angle of each arm, one of which serves as the madreporite.

Classification.—

Order 1. LYSOPHIUROIDEA. The two halves of the vertebral ossicles not united, ambulacral groove open. Extinct.

Order 2. STREPTOPHIUROIDEA Vertebral ossicles complete, articulate by ball and socket joints. Extinct and Recent. Examples: *Ophiomyxa* brittle star (Fig. 281).

Order 3. CLADOPHIUROIDEA. Vertebral ossicles articulate by hourglass-shaped joints. Arms often bifurcate. Examples: *Gorgonocephalus* basket star, *Astrophyton*.

Order 4. ZYGOPHIUROIDEA. Movements of the vertebral ossicles limited by lateral processes. Examples: *Ophiura, Ophiogypha* brittle stars.

ECHINOIDEA

The ECHINOIDEA include the sea urchins, cake urchins and sand dollars. Unlike the Asteroidea and Ophiuroidea, the echinids are globose, heart-shaped or cake-like and lack arms or rays (Fig. 287). The viscera is enclosed in a ***test*** of pentamerous plated box, the ***corona,*** bearing long, movable ***spines.*** The spines serve as levers in locomotion and prevent the sea urchin from rolling over.

The coronal plates are disposed in five ***ambulacral*** and five ***interambulacral*** areas. The ambulacral area comprises two columns of alternating plates, which meet in a zigzag median suture. The ambulacral plates are perforated by two rows of paired ***pores*** for the exit of the ***tube feet.*** At the summit are the five ***oculogenital plates*** surrounding the ***periproct.*** One of the genital plates is likewise the ***madreporite. Peristome*** is membranous or plated and surrounds the mouth The external surface bears numerous larger or smaller ***tubercles*** and ***spines.***

The alimentary canal lacks radial diverticula. The mouth is provided with five long curved, grooved ***teeth,*** set in a complicated skeleton

called ***Aristotle's lantern***. The lantern consists of 40 pieces : 5 ***teeth***, 5 ***pyramids*** each of two halves, 10 ***epiphyses***, 5 ***braces*** and 5 ***compasses*** each of two halves. The lantern surrounds the oesophagus and is provided with a complicated set of muscles that move its various parts. The food, consisting of sea weeds and small animals, is broken up by the lantern. In the cake urchins and sand dollars the lantern is absent.

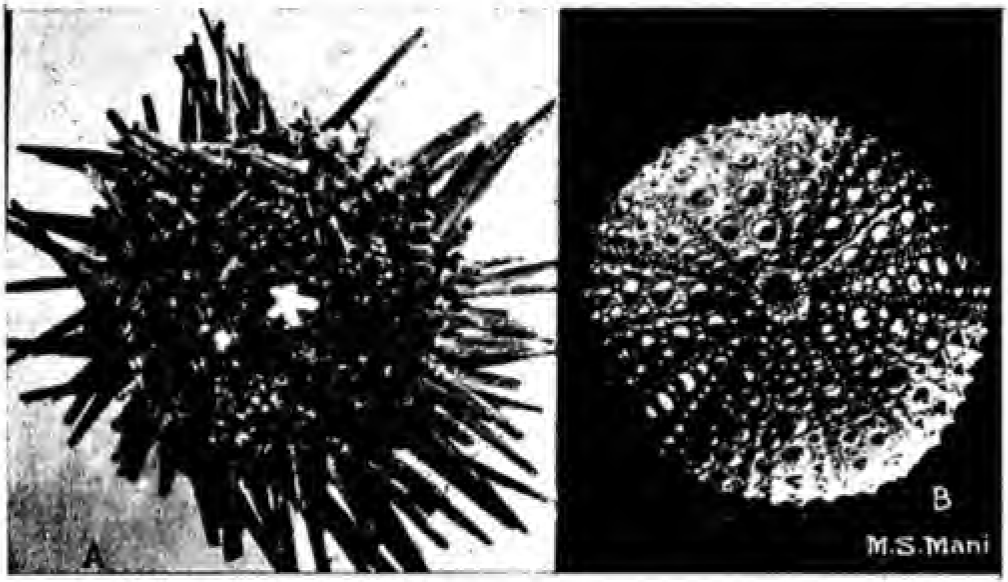


FIG. 287 Sea urchin A. The entire animal with the spines, in oral view. Note the white teeth of the Aristotle's lantern projecting through the mouth. B. After removal of the spines to show of the details on surface and the ambulacral pores, in aboral view. (*Original photograph of specimens in the Zoology Museum, St. John's College, Agra*).

The ***oesophagus*** (Fig. 288) ascends upwards in between the teeth of the Aristotles lantern. It continues into a thin-walled, slightly wider ***intestine*** coiled two and a half times (clockwise when viewed from the actinal side) and ends in the ***anus*** above. A narrow diverticulum, the ***siphon*** from the end of oesophagus accompanies the first part of the intestine into which it opens.

The numerous ***ciliated pore canals*** of the ***madreporite*** open into an ***ampulla***, that leads into the ***stone canal***. The stone canal lacks the calcareous rings of the starfish. The ring canal bears five interradial Tiedeman's bodies and gives off five ***radial canals***. These pass down to the radial nerve, then bend upward and run along the ambulacral areas on the interior of the corona. The radial canals give off numerous lateral canals opening into the tube feet. The latter have ampullae and suckers as in the starfish.

Respiration takes place by ten branched ***dermobranchiae*** arranged in a circle round the mouth. There is a pair of dermobranchiae opposite each ambulacral area.

The ***radial nerves***, external to the radial ambulacral vessels, arise from a ***nerve ring*** surrounding the mouth.

The sexes are separate. The reproductive organs in both the sexes are five grapebunch-like glandular masses adorally in the interambulacral area. Their ducts open to the outside on the genital plates.

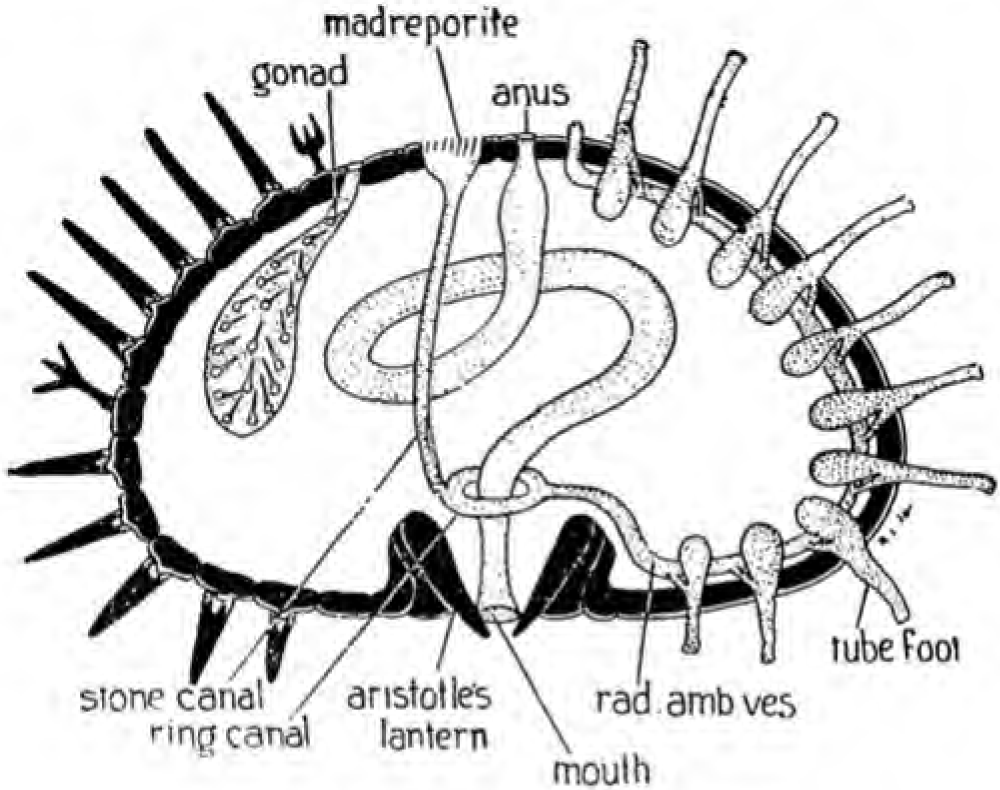


FIG. 258. Sea urchin. Vertical section.

The sea urchin may be considered as a starfish transformed by increase in vertical diameter of the disc and shortening of the arms. The ambulacral bands thus extend up to the adoral surface.

The cake urchins and sand dollars are flat forms with numerous small spines. They remain buried under sand just below the surface as the tide recedes but move about when the tide returns. A sea urchin from the gulf of Mexico has poisonous spines.

Classification.—

Order 1. BOTHRIOCIDAROIDEA. Extinct.

Order 2. CIDAROIDEA. Test regular. Two columns of plates in each ambulacrum and interambulacrum. Aristotle's lantern erect, with grooved teeth. No peristomal gills. Example: *Cidaris*.

Order 3. CENTRECHINOIDEA. Test regular. Two columns of plates in ambulacra and interambulacra. Ambulacral plates compound. Lantern erect, with keeled or grooved teeth. Peristomal gills present.

Suborder i. Anlodonta. Teeth grooved. Examples: *Aspidodiadema, Centrechinus.*

Suborder ii. Stirodonta. Teeth keeled. Epiphyses narrow. Examples: *Glyptocidaris, Stomopneustes, Arbacia* sea urchins.

Suborder iii. Camardonta. Teeth keeled. Epiphyses wide. Examples: *Echinus Salmacis, Stronyglocentrotus.*

Order 4. EXOCYCLIDEA. Test irregular. Periproct in an interambulacrum. Two columns of plates in ambulacra and interambulacra. Lantern present or absent.

Suborder i. Holectypina. Extinct.

Suborder ii. Clypeastrina. Ambulacral plates simple, petaloid dorsally. Lantern procumbent, without compass. Examples: *Clypeaster, Echinocyamus* sand dollars.

Suborder iii. Spatangina. Ambulacral plates simple, petaloid dorsally. No lantern. Examples: *Echinolampus, Hemiaster, Spatangus* heart urchins.

Order 5. PLESIOCIDAROIDEA. Extinct.

Order 6. ECHINOCYSTOIDEA. Extinct.

Order 7. PERISCHOECHINOIDEA. Extinct.

HOLOTHUROIDEA

The HOLOTHUROIDEA include the holothurians and sea cucumbers. They differ markedly from all other Echinodermata in their elongated sausage-shaped or worm-like bodies with little or no skeleton. The mouth and anus are more or less nearly terminal at opposite ends and the former is always surrounded by a circle of ***tentacles***. There are no arms, spines or pedicellariae. Skeleton is vestigial and consists of only isolated nodules of calcium carbonate imbedded in the skin.

Holothurians resemble Echinoidea in that the ***radial canals*** run backwards and upwards from the ring canal over the inner surface of the body and terminate on small ***papillae*** near the anus.

Body wall is provided with transverse muscles running along the radii, by means of which worm-like contractions of the body are carried out.

The ***oral tentacles*** are comparable to the oral tube-feet of Ophiuroidea and Spatangoidea. ***Tube feet*** are distributed over the surface in five radii: three of the radii are situated on the lower and two on the upper surface.

Alimentary canal (Fig. 289) runs backward to the posterior end of the body, then forward to the anterior and finally turns backward to the anus. It makes one and a half turns round the longitudinal axis and is suspended by three ***mesenteries***. It is differentiated into oesophagus, stomach, intestine and cloaca. The cloaca not only serves for passing faeces but also functions as respiratory organ by pumping water in and

out. Two long branched tubes, the ***dendriform organs*** or ***respiratory trees***, open into the cloaca and into these the inspired water passes. Finer branches of these end in ***ampullae***. When water is forced into the ampullae, they become tense and a considerable quantity diffuses through their walls.

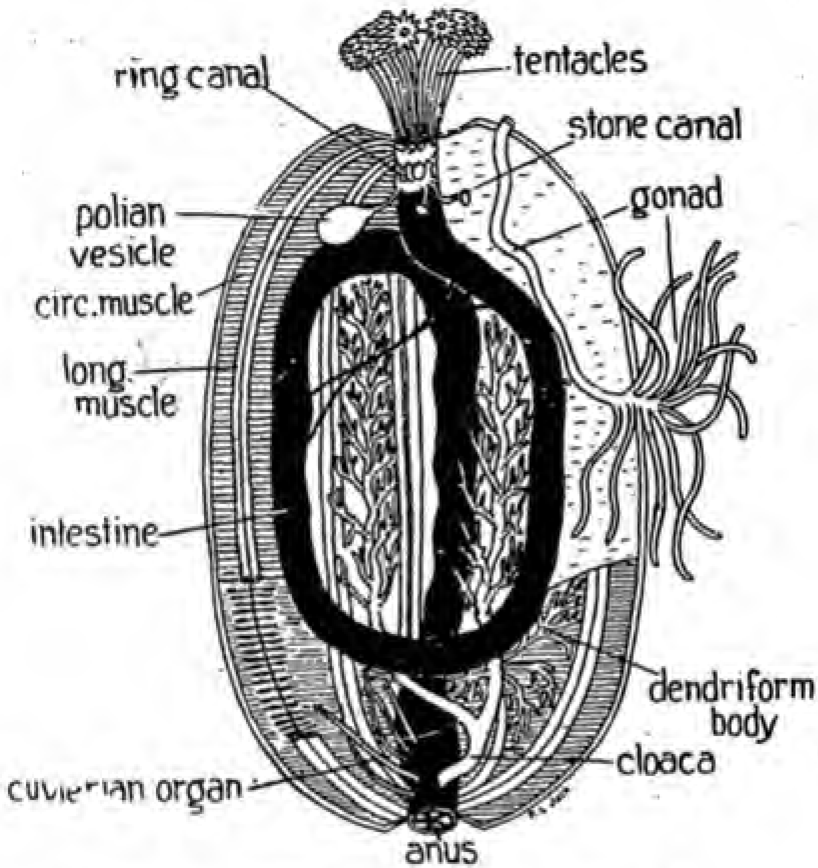


FIG. 289. *Holothuria*. Internal structure. (*Modified from Richard Hertwig, Jena, Gustav Fischer*).

The water vascular system generally resembles that of Echinoidea. The stone canals are usually five and do not reach the body wall. Each ends in a swelling "the internal madreporite" projecting into coelom. The stone canal and madreporite are stiffened by calcium carbonate.

Classification. —

Order 1. ASPIDOCHIROTA. Tentacles with branches crowded on a circular disc. Example: *Holothuria*.

Order 2. DENDROCHIROTA. Tentacles branched irregularly. **Examples:** *Thyone*, *Cucumaria* sea cucumber.

Order 3. MOLPADONIA. Tentacles small. No tube-feet. **Example:** ***Caudina***.

Order 4. APODA. (=Synaptida). No tube-feet and dendriform organ. **Example:** *Synapta*.

CRINOIDIA

The CRINOIDEA include the flowerlike sea lilies and feather stars. The body comprises a cuplike ***calyx*** of calcareous plates borne on a flexible jointed ***stalk*** with rootlike growths in the sea bottom. The calyx bears ten or more ***arms*** that have numerous lateral ***pinnules***. The upper surface of the calyx is the ***oral side*** ; both mouth and anus open on this surface. The anus is situated on a raised cone. Open ***ambulacral grooves***, lined by cilia and tentacle-like tube feet, run in the oral side of the arms. There is no madreporite. The gonads develop in the pinnules.

FIG. 290. Class Crinoidea : *Antedon*.

The Crinoids have practically no enemies. *Myzostoma* a peculiar (Polychaete) Annelid often occurs on the arms and calyces of the Crinoids. Several of the Crinoids are stalked and grow in extensive submarine gardens. Others like *Antedon*, are stalked only in the larval stage, but swim freely as adult.

A Crinoid may be considered as a starfish attached by a stalk on the adoral surface and with the oral surface turned upward. The arms correspond to the arms of the starfish and the calyx to the disc.

Classification.—

Order 1. CAMERATA. Extinct.

Order 2. FLEXIBILIA. Extinct.

Order 3. INADUNATA. Extinct.

Order 4. ARTICULATA. Mouth and food grooves open. Examples : *Pentacrinus*, *Antedon* sea lily.

Development of Echinodermata.—The eggs and sperms are shed into the sea, where fertilization takes place. The cleavage is total and equal A ciliated ***blastula*** escapes from the egg shell and swims about by the activity of the cilia. Invagination of the ***blastoderm*** on one side leads to a ***gastrula,*** with archenteron and blastopore. The blastopore site is destined to become the anal end of the future adult as in the frog. One side of the gastrula becomes somewhat concave. The cilia now become restricted to a thick band around this area and

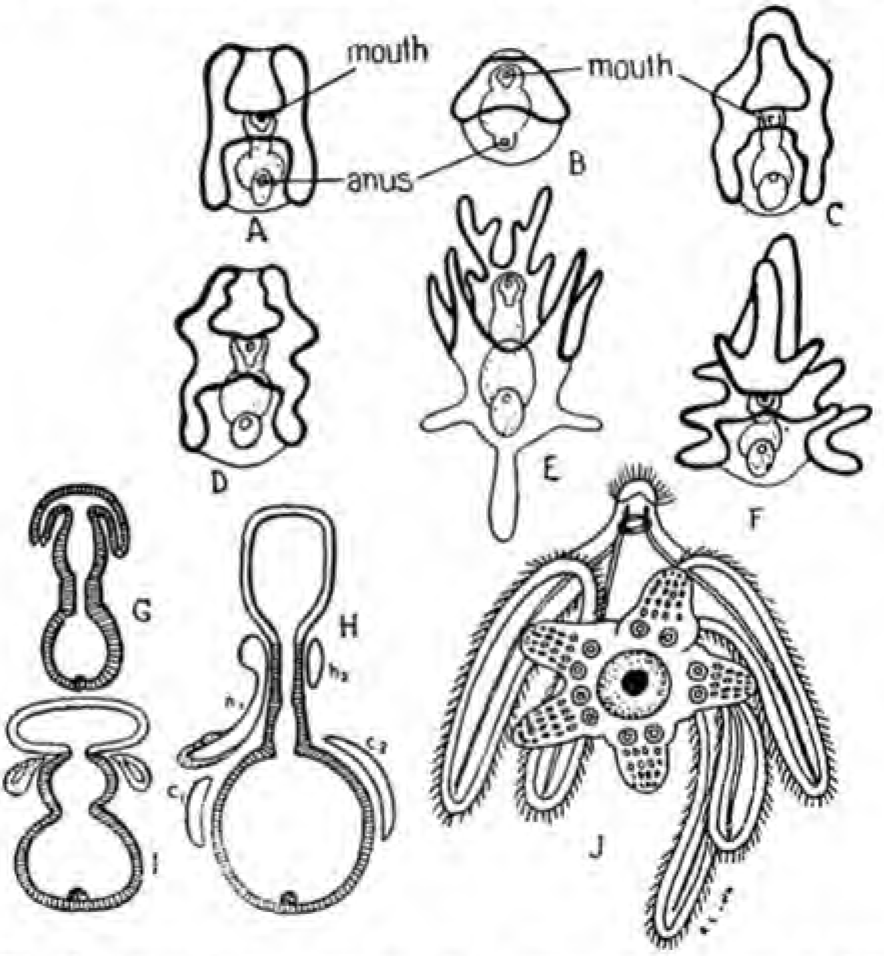


FIG. 291. Larvae of Echinodermata. B. Generalized first larva. A. & D. Stages of the auricularia larva Holothuroidea. C. & F. Stages of the bipinnaria larva of Asteroidea. E. Echinopluteus larva of the Echinoidea. G -I. Stages in the formation of coelom and the development of the water vascular system in sections. J Formation of *Ophiura* from the ophiopluteus larva of the Ophiuroidea. (*After Johannes Muller, redrawn from Richard Hertwig, Lehrbuch der Zoologie, Jena, Gustav Fischer.*)

thus give rise to the characteristic ***ciliated band***. The ciliated band is the organ of locomotion for the larva. Stomodaeal invagination produces a mouth and opens into the oesophagus, stomach and intestine. The digestive tract is V-shaped. The larva at this stage is called a ***dipleurula.*** The dipleurula (Fig. 291) is differently modified in different groups.

According to the arrangement and number of the ciliated bands and lobes, we have the ***brachiolaria*** and ***bipinnaria*** larvae of the starfish, the ***pluteus*** larvae of the brittle star and sea urchin and ***auricularia*** larva of the holothurians. After a few weeks of free-swimming life, the larva settles down to the sea bottom and becomes fixed by the anterior end. The posterior end of the fixed larva now enlarges and bends to the left. Five lobes appear on the right side that develops into the aboral surface of the future adult. The left side becomes the oral surface. Paired outgrowths from the coelom of the left side become the first tube feet. Metamorphosis leads to the formation of the adult.

Affinities.—The Echinodermata exhibit some characters of the phylum Chordata : 1. The mesodermal endoskeleton, 2. the blastopore becoming the anus of the adult and not mouth as in Mollusca and Annelida, 3. mesoderm forming as pouches from the archenteron and not from special mesoblast cells as in Mollusca and Annelida, 4. the larvae resembling the ***tornaria*** larva of *Balanoglossus*, one of the primitive Chordates. The Echinoderms are therefore close to the Chordata. They have evidently ***retrogressed*** greatly from a more advanced ancestor. This is due to their having passed through a ***fixed*** stage in their history : the radial symmetry and absence of head are adjustments of a sessile animal to meet the environment on all sides.

RESUMÉ

1. The Echinodermata are wholly marine animals that have a mesodermal skeleton of calcareous plates and spines imbedded in their skin.

2. The organs exhibit a pentamerous arrangement.

3. The alimentary canal extends into the arms of the starfish but not in the other members of the phylum.

4. The water vascular system includes a madreporite, a stone canal, ring canal and a radial canal that opens into the tube feet often provided with ampullae and suckers.

5. The larvae of the Echinodermata are ciliated and bilaterally symmetrical and greatly resemble the tornaria larva of *Balanoglossus* (Urochorda : Chordata).

6. The Echinodermata include the **Asteroidea** (starfish), the Ophiuroidea (brittle star), Echinoidea (sea urchin), Crinoidea (sea lily) and the Holothuroidea (sea cucumber).

CHAPTER XVII

CHORDATA

Distinguishing features.—The CHORDATA are recognized by three distinctive characters: 1. notochord, 2. single tubular nerve cord dorsal to the digestive tract and 3. pharyngeal slits.

The ***notochord*** is a stiff but elastic rod of cells mostly derived from the endoderm. It lies between the spinal cord and the alimentary canal. It acts as a stiffening endoskeleton for the body. Nothing like it is found in the other Phyla, but it is present in all the Chordates. The name Chordata is indeed derived from ***chorda dorsalis*** or notochord. In some Chordates it forms the permanent endoskeleton but in most others it is surrounded by cartilegenous or bony ***vertebrae.*** The backboned animals or Vertebrata are Chordates in which the notochord develops in the embryo but later becomes surrounded by cartilage or bone or both to form the vertebral column.

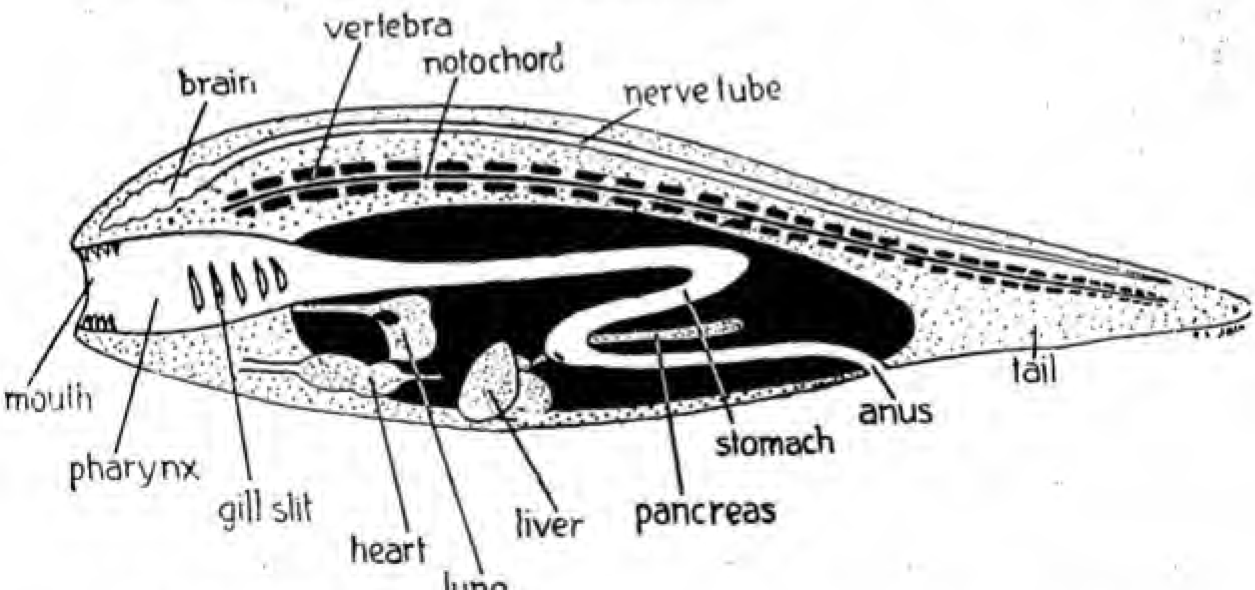


FIG. 292. Diagram of the vertebrate plan of body: a dorsal tubular nervous system, a notochord as foundation of the vertebral column, an alimentary canal with liver, the pharynx with gill slits, gills or lungs or rarely both, and a ventral heart.

The ***nerve cord*** is a single, hollow, tube-like structure lying dorsally to the notochord and to the alimentary canal. It arises as a groove of the ectoderm on the dorsal side of the embryo. The groove deepens

until the edges meet above and enclose a tube. When first formed, this tube opens anteriorly to the outside and curves posteriorly down the hind end of notochord to open into the archenteron (Fig. 298). Later the openings to the outside and into the archenteron are obliterated and the ***neural tube*** results. The cavity of the neural tube is the ***neurocoel***. In many Chordates the neural tube enlarges anteriorly to form the brain. The *tubular* nerve cord of the Chordates thus differs radically from the *solid* nerve cord of Annelids and Arthropods. In these phyla the nerve cord is also ventral to the gut but in the chordates dorsal.

The ***pharyngeal slits*** are a series of paired openings from the pharynx to the outside. These slits appear in the embryos of all Chordates. In fishes they persist throughout life as ***gill slits*** and function as respiratory organs, but in other Chordates that breathe by lungs, the pharyngeal slits disappear as the embryo grows older. Pharyngeal slits never develop in any other phyla.

Other chordate characters.—The other characters of the chordates are : 1. bilateral symmetry, 2. diminishing metamerism, 3. endoskeleton, 4. cephalization, 5. centralization of the nervous system, 6. localized respiratory system, 7. closed circulatory system, 8. ventral position of heart with reference to the digestive tract,. 9. presence of liver and 10. of hepatic portal circulation.

Bilateral symmetry of the body is common to Chordata and several other non-chordata, for example, Annelida and Arthropoda. The body is so organized that an imaginary line drawn through a sagittal plane through the median longitudinal axis divides it into two identical halves.

Annelids and Arthropods are metamerically segmented animals. Typically the body of an Annelid is composed of a series of metameres similar externally and internally. In the Arthropods the metamerism is generally clear externally but less evident in the internal organization. In the Chordates the evidence of metamerism lies only in the internal organs. In the primitive Chordates and in the embryos of the higher ones, the body muscles are segmentally arranged as ***myomeres***. The renal tubules, the vertebrae and the spinal nerves are also vestiges of diminishing metamerism. In Annelids and Arthropods each segment has typically a pair of appendages, but no Chordate has more than two pairs of appendages.

The endoskeleton of the Chordates consists primitively of the notochord. It forms a rigid and at the same time sufficiently elastic support for the muscles used in locomotion. In most Chordates, the notochord is replaced by cartilagenous or bony endoskeleton.

Cephalization or the formation of a distinctive head is met with in Arthropods and Chordates. The head consists largely of brain, the organs of special sense and their protective structures. The cephalization reaches its maximum among the Chordata.

The increasing cephalization is really an outward expression of the centralization of the nervous system in the anterior region of the body. The brain and the spinal cord become the commanding parts Starting from the fishes as we ascend higher and higher up to the mammals, there is increasing centralization in the brain and better co-ordination of various organs.

The respiratory function is localized in the pharynx. The pharynx is pierced by the gillslits through which the water passes out on to the gills. When lungs are developed from the pharynx, the gill slits get closed.

The circulatory system of the Chordates is a closed system. In most chordates the blood contains erythrocytes, which are not met with in non-chordates. The heart is also an improved one. The heart lies ventrally of the alimentary canal and the main arterial trunk dorsally. The flow of blood in the dorsal aorta is from the front backwards and the venous current from behind forwards in the ventral vessel.

Liver and pancreas are universally present in Chordates. The venous blood from the intestine first passes through the liver on its way back to the heart ; there is always a hepatic portal circulation in the Chordates ; some have a renal portal system also.

The essential features of the chordate plan (Fig. 292) of build as distinct from the Annelidan are : 1. the dorsal nervous system, 2. dorsal aorta and 3. ventral heart. The body of a Chordate may therefore be considered as corresponding to that of an Annelid turned upside down. The main difference between the arthropodan and chordate plans lies in the presence or absence of an axial endoskeleton.

The terms Chordata and Vertebrata are not synonymous. All Chordates are not Vertebrates but all Vertebrates are Chordates. Many Invertebrates are thus Chordates and all non Chordates are Invertebrates. Chordata are animals with notochord and Vertebrata possess a vertebral column round the notochord.

Classification.—The Chordata include 1. Hemichordata, 2. Urochordata, 3. Cephalohordata and 4. Vertebrata. The first three subphyla are usually grouped together as *Protochardata* as distinct from the Vertebrata. The Protochordates differ sharply from the Vertebrata in lacking distinct cranium, jaws, vertebrae and paired appendages They are therefore also often referred as *Acrania*.

Phylum CHORDATA

Group I. *PROTOCHORDATA* or *ACRANIA*. Without cranium, vertebrae, jaws or paired appendages.

Subphylum 1. HEMICHORDATA

Subphylum 2. UROCHORDATA

Subphylum 3. CEPHALOCHORDATA

Group II. *VERTEBRATA* or *CRANIATA*. With cranium and vertebral column.

HEMICHORDATA

The HEMICHORDATA. (*hemi*=half; *chorda*=cord) include worm-like animals, for example *Balanoglossus*, that live in burrows in the muddy bottom of the shore. The body comprises a ***proboscis*** in front, a ***collar*** and a ***trunk*** behind. The pharynx is pierced by gill slits. A dorsal anterior blind process of the alimentary canal represents the norochord and stiffens the proboscis which is used in burrowing. There is also a dorsal tubular nerve cord. While burrowing, the animal swallows the mud and digests any organic particles in it in much the same way as the earthworm. During development, a ciliated free-swimming ***tornaria*** larva undergoes metamorphosis before becoming the adult. This larva resembles the larvae of Echinodermata.

1 BALANOGLOSSUS

External features.—*Balanoglossus* (Fig. 30) is a soft-bodied cylindrical worm-like animal that burrows in sand in the sea bottom. It lives in a loose tube of sand grains cemented together by a viscid secretion from integumental glands. As the animal burrows, a quantity of sand enters through the ever open mouth and passes out by the anus.

The body comprises a muscular ***proboscis*** in front, a ***collar*** immediately behind and a long somewhat depressed ***trunk***. The proboscis is a hollow subconical structure that is used in burrowing. Its cavity opens dorsally to the outside by a minute ***proboscis pore***. The sea water that enters through the pore keeps the proboscis turgid. The collar is a stout muscular band. Its cavity is completely cut off from that of the proboscis and is also divided by dorsal and ventral ***mesenteries*** into right and left halves. It opens to the outside by paired ***ciliated tubes*** ending in the ***collar pores*** in the first gill slit. A double row of small ***gill slits*** open dorsally in a longitudinal furrow on the anterior part of the trunk. The number of the gill slits increases with age.

Alimentary canal.—The ***mouth*** is a permanently wide open aperture ventrally at the base of the proboscis, within the collar. It leads into a ***pharynx***, the dorsal wall of which is pierced by internal

U-shaped gill slits (Fig. 293). The gill pouches are strengthened by separate chitinous rods. Behind the pharynx, the alimentary canal is a nearly straight tube that ends posteriorly in the ***anus***. The paired ***hepatic caeca*** about the middle of the digestive tract are indicated externally by a series of bulges. The alimentary canal is supported by dorsal and ventral ***mesenteries***. The roof of the alimentary canal is produced forward as a diverticulum, the ***notochord***, into the cavity of the proboscis.

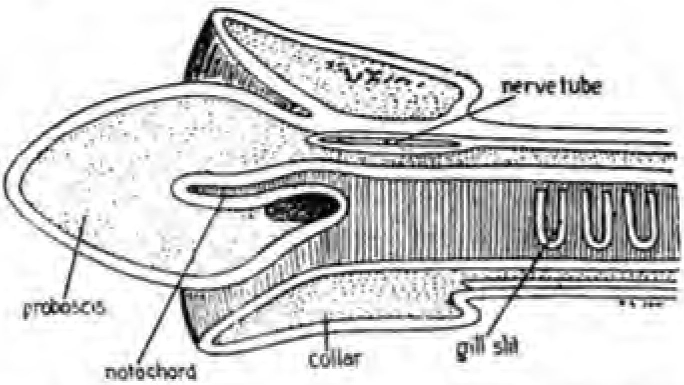


FIG. 293. *Balanoglossus*. Anterior end in sagittal section.

Circulatory system and coelom.—The circulatory system includes a ***dorsal longitudinal*** and a ***ventral longitudinal*** vessel. These vessels are connected by transverse branches at intervals. The dorsal vessel ends anteriorly in a ***heart*** partly in the collar and partly in the neck of the proboscis. The coelom is represented by five cavities: one in the proboscis and a pair each in the collar and trunk.

Excretory system.—The excretory organ consists of a ***glomerulus*** or plexus or blood vessels at the anterior end of the notochord.

Nervous system.—There are ***dorsal*** and ***ventral nerve cords*** extending the whole length of the body. The dorsal cord encloses hollow spaces in the collar region. The ventral and dorsal cords are connected together by a nerve band in the collar. Nerves are given off at frequent intervals from the nerve cords. There are no organs of special sense.

Reproductive system.—The sexes are separate The gonads are sac-like structures in a double series along the gill region and part of the trunk directly behind. They open to the outside by a series of ***genital pores***.

Development.—Fertilization is external. Complete and equal cleavage results in a ***blastula***. Flattening of one side of the ***blastoderm*** is followed by invagination of the flattened side. A ciliated ***gastrula*** is

thus formed. The ***blastopore*** closes and the embryo elongates. Stomodaeal invagination of the ectoderm gives rise to the ***mouth*** in a transverse constriction in the equator of the embryo. The ***anus*** appears at the side of the closed blastopore by a proctodaeal invagination. The archenteron gives off two ***coelom pouches***. Another transverse constriction divides the body into anterior, middle and posterior parts, that represent respectively the proboscis, collar and trunk of the future adult. Paired gill slits appear very soon and the adult stage is gradually reached.

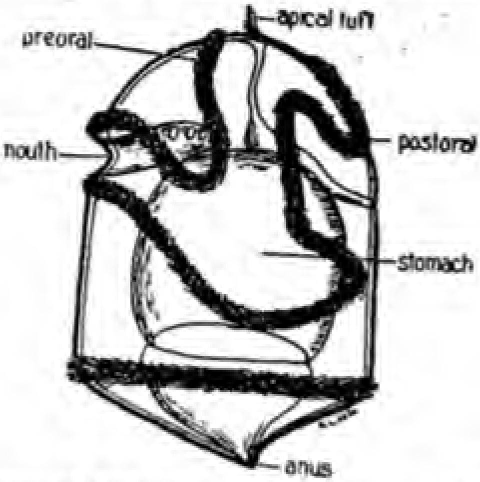


FIG. 294. Tornaria larva of *Balanoglossus*. It is essentially a trochophore larva.

In some species the gastrulation is followed by a ciliated larva, the ***tornaria*** (Fig. 294), reminding one of the trochophore of the Annelid and Mollusca and greatly resembling the larvae of Echinodermata. The tornaria has a looped ***preoral*** and a ***postoral*** band of cilia, a curved alimentary canal, an ***apical plate*** containing nerve cells, eye spots and tuft of cilia. As the development proceeds, the apical plate and the ciliated bands disappear. The proboscis develops as an outgrowth and the collar becomes constricted. The metamorphosis is completed by the posterior part elongating into the trunk of the adult.

UROCHORDATA

The UROCHORDATA (*oura*=tail) comprise the tunicates or sea-squirts (Ascidians). The adult is a fixed animal, enclosed in a cellulose ***tunic*** or test. When irritated, the animal squirts water. The body has two openings : ***mouth*** and ***atrial*** openings. Water enters through the mouth, passes into the pharynx, out through the gill slits into the atrium, whence it comes to the outside by the atrial opening. Sticky mucus secreted by a ciliated groove—the ***endostyle***—of the pharynx entangles minute particles of food. There is no notochord and no tubular nerve. The larva on the other hand resembles the tadpole of a frog.

It has a notochord in the long tail, a tubular nerve that is enlarged anteriorly into brain, eyes, etc. After a brief free-swimming life, the ***tadpole*** larva settles down on some solid object and becomes fixed. It undergoes metamorphosis : loses the tail, notochord, nerve tube and sense organs and finally becomes the degenerate sea-squirt. Its metamorphosis is ***retrogressive*** as compared with that of the frog or of the butterfly.

2. HERDMANIA

Herdmania is the common Ascidian or sea squirt of the Indian waters. Sea squirts occur on rocky sea shores. They are so called because when disturbed, they forcibly eject fine jets of sea water through two holes. Though many are simple, others give rise to colonies by budding.

Systematic position.—

Phylum CHORDATA
  Class *UROCHORDATA* (=Tunicata)
    Order ASCIDACEA. Sessile, simple or colonial forms with the atriopore dorsal.
      Family *TETHYIDAE*
        Genus *Herdmania*
          Species 1. *pallida* 2. *ceylonica* 3. *mauritiana*

External features.— The body of an Ascidian is essentially a cylinder, fixed to rock or wooden pile of wharfs by its broad base. At the free end are a large circular ***oral aperture*** and a somewhat smaller ***atrial aperture***, slightly to one side. Strong sphincter muscles close the two apertures. A current of water flows into the body through the oral aperture and leaves the body through the atrial aperture. The body is enclosed in a loose ***tunic*** or test of a soft translucent material called ***tunicin***, chemically related to cellulose of plants. Beneath the tunic is the ***mantle*** or the soft body wall proper. The body is freely suspended within the tunic, to which it is attached by the ***oral*** and ***atrial siphons*** at the two apertures.

Alimentary and respiratory systems.—The oral aperture leads into the oral siphon. The oral siphon passes below into a large ***pharynx*** or ***branchial chamber*** (Fig. 295). The walls of the pharynx are pierced by numerous ***gill slits*** or ***stigmata*** arranged in transverse rows. The water that enters the pharynx through the oral aperture passes through the stigmata to oxygenate the blood in the caprillaries. It then escapes into the ***peribranchial chamber*** or ***atrium*** surrounding the pharynx. From the atrial chamber the water passes to the outside by the atrial aperture. The current of water is set up by the action of cilia that cover the edges of the gill

slits. The pharynx is attached to the mantle along one side—the ventral surface. On this side the pharyngeal wall has a groove, the ***endostyle.*** Ciliated and gland cells line the endostyle. The gland cells secrete a mucus, which entangles minute particles of food in the current of water. The action of the cilia drives these particles to the ***peribranchial groove*** in front, whence they pass to the ***dorsal lamina*** a prominent ridge on the side of the phryngeal wall opposite the endostyle. The cilia of the dorsal lamina drive the particles finally into the

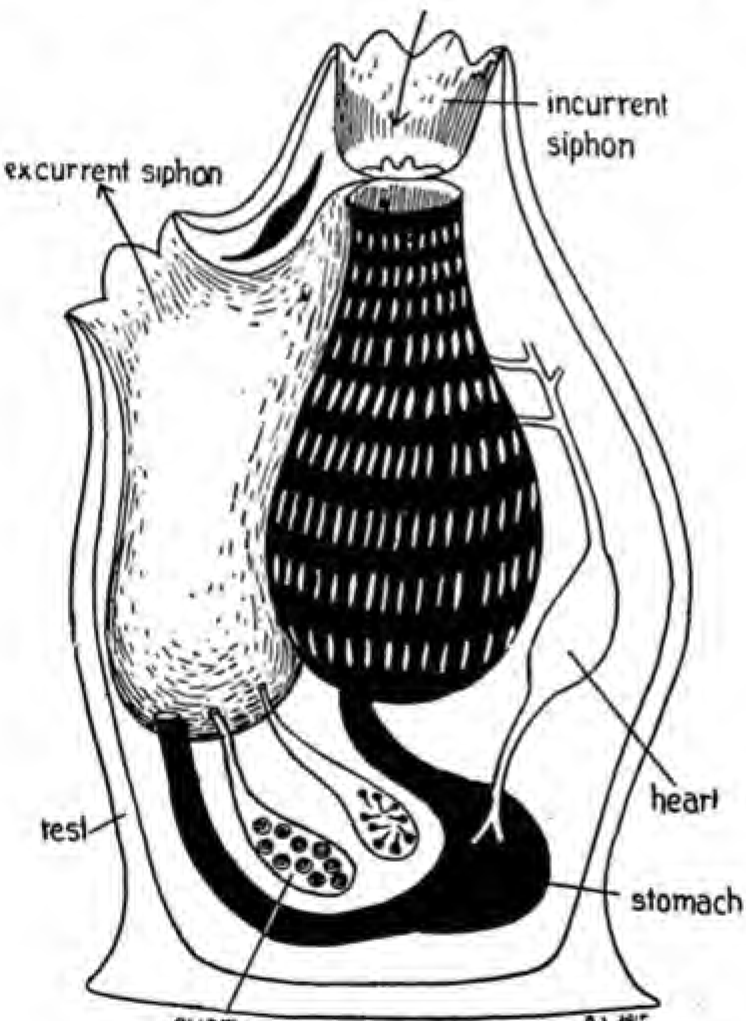


FIG. 295. Structure of a typical ascidian.

oesophagus. The oesophagus leads to the ***stomach*** and ***intestine*** lying on the left side in the mantle. The intestine is formed into a double loop and terminates in the ***anus*** within the atrium. The ***liver*** is a chocolate-coloured bilobed mass largely covering the stomach.

Circulatory system.—The blood consists of a nearly colourless plasma with pigmented corpuscles and leucocytes. The well developed circulatory system includes a simple muscular ***heart*** enclosed within a ***pericardium*** near the stomach. A ***cardiobranchial*** artery from the heart continues into the ***ventral aorta.*** The ventral aorta gives off ***transverse vessels*** running between the transverse rows of stigmata. These vessels give off numerous capillaries into the pharyngeal wall to facilitate oxygenation of the blood. The transverse vessels then open into a ***dorsal aorta.*** From the dorsal aorta blood vessels are given off to the intestine and the gonads. A ***cardiovisceral*** vessel from the heart supplies the stomach and the gonads. The contractions of the heart are off a peristaltic character. Waves of contractions follow from one end to the other. After a pause, the direction of the peristalsis is reversed. The direction of the flow of blood is thus reversed at regular intervals.

Nervous system.—A minute ganglion in the median dorsal line between the mouth and atrial siphon represents a degenerated brain. It gives off nerves to the siphons and other neighbouring parts. Scattered sensory receptor cells occur in the tunic.

Excretory system.—The ***neural glands,*** just above the nerve ganglion, comprise a number of branching tubules, some of which open into a ***ciliated canal*** in the gland. The ciliated canal leads into a duct, opening by a ***ciliated funnel*** into the branchial cavity.

Reproductive system.—Sea squirts are hermaphroditic but ***protandrous*** and self fertilization is thus avoided. There are two gonads imbedded in the mantle. The left gonad lies within the loop of the intestine and the right gonad lies close to the heart. Their ducts open into the atrial cavity. Each gonad consists of an inner ***ovarian zone*** surrounded by an outer ***testicular zone.***

Development.—Fertilization is usually external in the sea squirts. The zygote undergoes complete and equal cleavage. In the eight cell stage four cells are smaller and four cells are larger. The flattened blastula is called ***placula.*** The placula becomes curved into a hollow cup, with endoderm inside and ectoderm outside. A ***gastrula*** is thus formed. The ***blastopore*** gradually narrows down to a minute ***dorsal pore.*** The embryo now elongates and becomes flattened on the side destined to become the dorsal surface of the larva. The ectoderm cells in the median line of the dorsal side become differentiated into a ***medullary plate.*** The cells on either side of the medullary plate become elevated into ***neural folds,*** enclosing a ***neural groove*** in between.

The neural groove finally closes from behind forward thus giving rise to the ***neural tube***, opening in front by a small ***neuropore***. The ectoderm below the small blastopore grows over the neural groove, thus putting the archenteron in communication with the ***neurocoel*** or the cavity of the neural tube by means of the ***neurocentric canal***. The roof of the archenteron gives off a longitudinal fold that develops into the ***notochord***. Laterally paired strands of ***mesoderm*** are given off by the endoderm. The embryo soon assumes a tadpole-like appearance and possesses an elongate compressed tail, with notochord and muscles. Three ***adhesive papillae*** develop at the anterior end. The neutral tube enlarges anteriorly to form the ***sense***

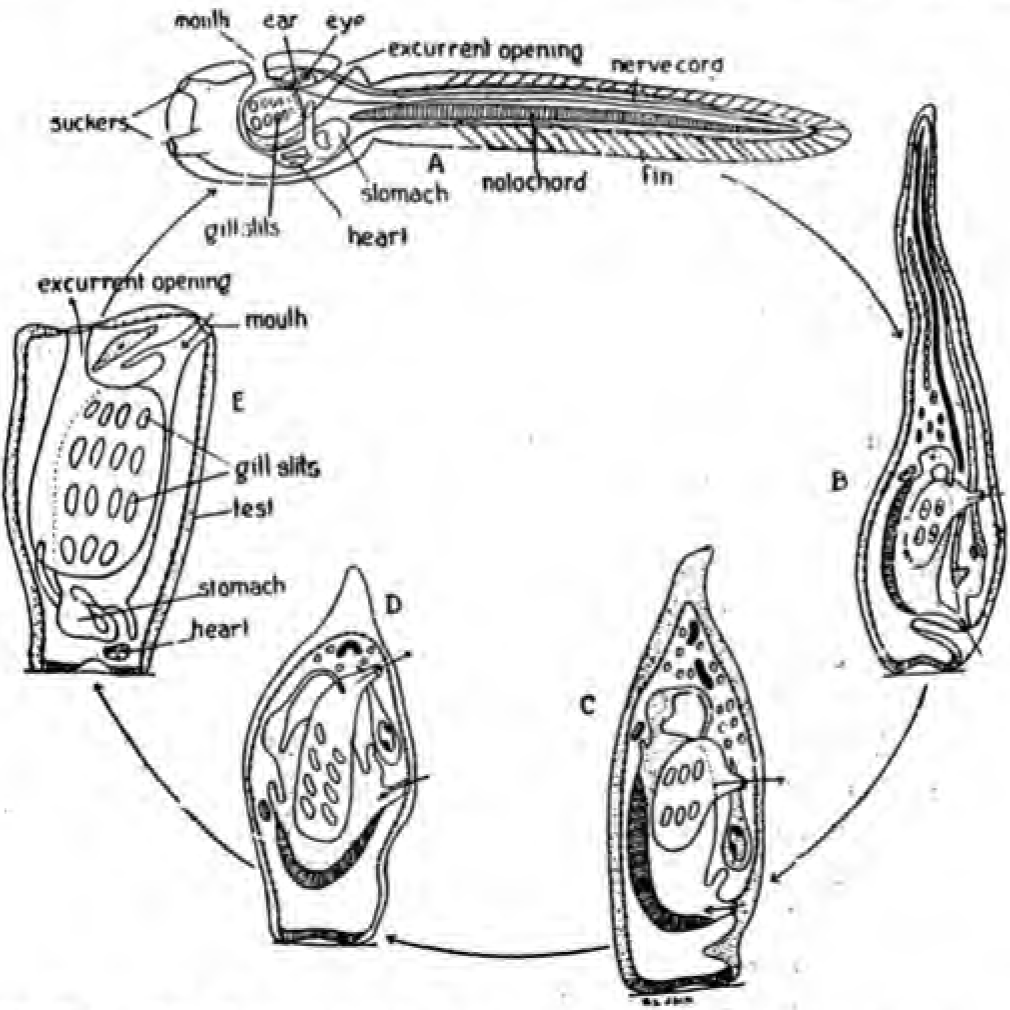


FIG. 296. The life cycle of an Ascidian. A. Tadpole larva, free-swimming. B. Tadpole settles down. C-D Retrogressive metamorphosis. E. Adult. (*The larvae after Kowalewsky*).

vesicle (corresponding to the brain of the tadpole of the frog). ***Eyes*** and ***otocysts*** (ear) develop in association with the sense vesicles.

The alimentary canal becomes differentiated into a pharynx, pierced by gill slits, a stomach and intestine. A stomodaeal invagination of the ectoderm gives rise to the mouth. Heart and blood vessels appear and the atrium develops. The larva—now a ***tadpole***—hatches at this stage and leads a free-swimming life for some time—a few hours to days.

The tadpole larva then (Fig. 296) settles down to some suitable rock and becomes attached by means of the adhesive papillae. A number of gill slits close up. The tail gradually reduces and finally disappears. With the tail, the notochord and nerve cord are also lost. The eye and the otocyst disappear. The gonads develop. The larva thus undergoes metamorphosis into the adult.

The metamorphosis involves the change from a free larva with chordate characters into a fixed adult without chordate characters. It thus differs radically from the metamorphosis of the frog. There is no increase in the complexity of organization during the metamorphosis of the ascidian tadpole into the adult sea squirt but on the other hand simplification takes place. The ascidian tadpole thus undergoes degeneration from a Chordate to a Non-Chordate. Its metamorphosis is thus ***retrogressive:*** stepping backward.

Among the other important changes during the retrogressive metamorphosis are 1. the formation of tunic, 2. the formation of a peribranchial space by the fusion of the paired integumental perithoracic vesicles and 3. partial rotation of the body involving the approximation of the mouth and anus.

Relation to other animals.—In their tadpole stage the sea squirts have numerous enemies, but as adults are comparatively safe. Several animals are generally associated with them. Small Pelecypods inhabit the tunic. Polyps, sea anemones, branacles, gastropods and other similar small animals often become attached to sea squirts. They are also frequently covered by the green plant alga. A crustacean breeds in their cavities.

CEPHALOCHORDATA

The CEPHALOCHORDATA (*kephale*=head, *chorde*=cord) are small marine animals, pointed at both ends, as for example in *Amphioxus*. The amphioxus measures at about two to three inches long and is widely distributed in all tropical and subtropical regions. It is extensively used as food in China. It remains in burrows in clean sand near the

shore with only the mouth projecting above the surface. Amphioxus resembles the simpler Vertebrata in several respects. The notochord extends the whole length of the body and serves as a stiffening rod for the body. The tubular nerve is dorsal and is enlarged anteriorly into a brain.

The mouth is surrounded by delicate ***cirri***. The pharynx has over fifty pairs of rows of gill slits strengthened by ***gill bars***. The slits open into an ***atrium*** formed by a fold of integument. The atrium opens to the outside by the ***atriopore*** far anterior to the anus. There is a liver. The dorsal vessel carries the oxygenated blood from the front backwards. The subintestinal vein enters the liver. The hepatic vein from the liver carries the blood to the ventral aorta and thence to the gills.

The excretory system is of the non-chordate type and comprises a series of paired nephridia, which discharge into the atrium. The sexes are separate; twenty-six pairs of gonads lie on either side of the pharynx.

During the breeding season the amphioxus leaves its burrows and swims towards the evenings. The sperms and ova are shed in the water, where fertilization takes place. The zygote undergoes total and equal cleavage. Development is without metamorphosis.

3. AMPHIOXUS

Amphioxus (= sharp at both ends), a superficially fishlike animal, occurs in sandy bottom of shallow seas. It differs from fishes in lacking a definite head and paired fins. It swims in the water by undulating movements of its body. It prefers usually to remain buried in the sand in the vertical posture, with only its anteriror end just protruding above the surface. While thus remaining under the sand, it draws a current of water into the mouth and secures minute organic particles for food. It has great powers of burrowing.

External features.—The body is compressed and pointed both anteriorly and posteriorly (hence the name). There is no head. The surface of the body is marked by V-shaped lines that indicate the internal bundles of muscles, the ***myotomes***. The myotomes of the right side alternate with those of the left. A membranous ***median dorsal fin*** extends from the anterior end to the posterior, where it expands into a ***caudal fin***. There is also a ***ventral median fin*** for a short distance. The dorsal fin is strengthened by about 250 cartilagenous rods, the ***fin rays***. The fin rays of the ventral fin are paired and there are about fifty of them. In front of the ventral fin there are lateral finlike expansions

of the integument, the ***metapleur***. The metapleur extends in the form of a triangular flap, fringed by tentacle-like ***buccal cirri***. The flaps of the

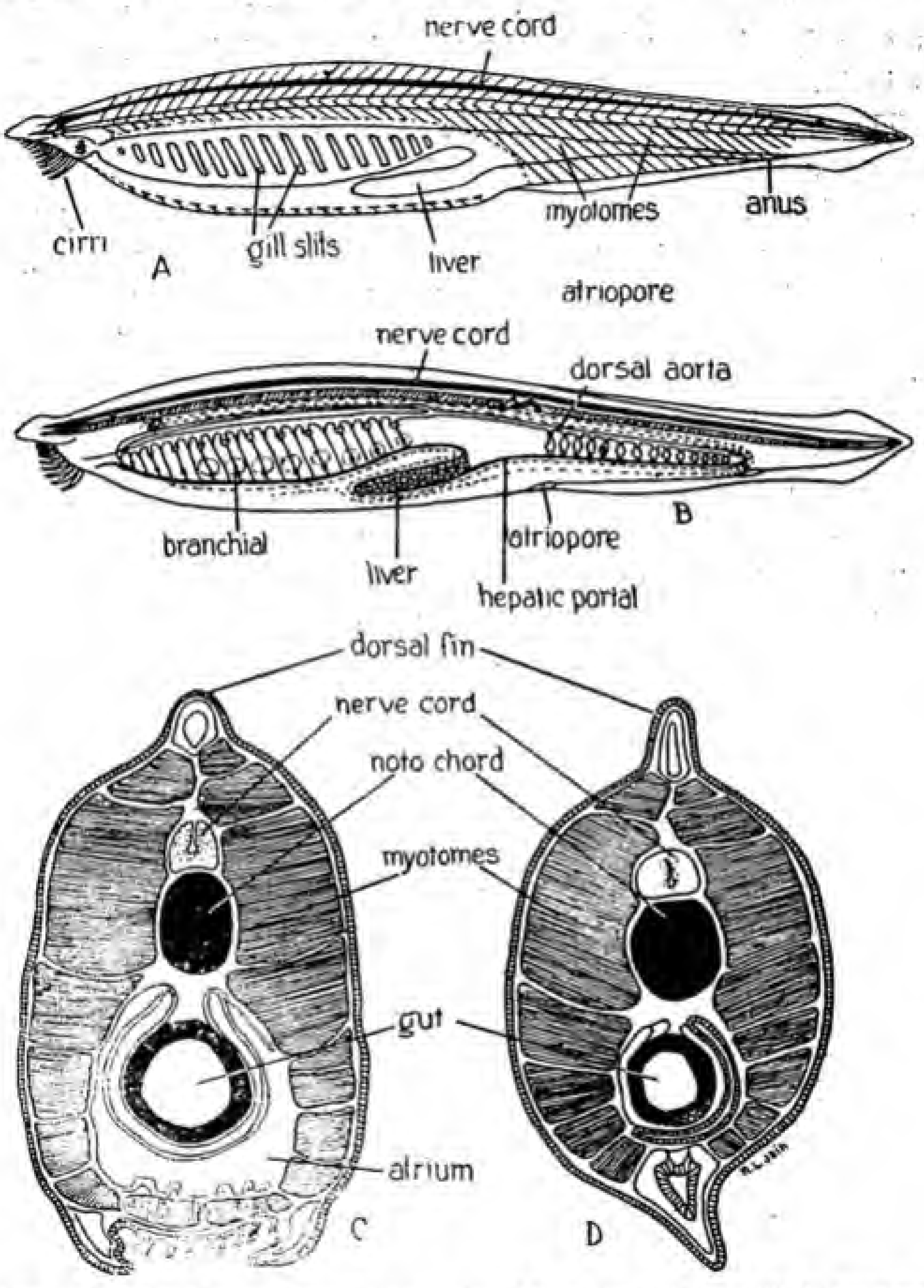


FIG. 297. *Amphioxus lanceolatus.* A. Alimentary and respiratory organs from the left side seen as transparent objects from a cleared specimen. B. Circulatory system. C. Transverse section in front of the atriopore. D. Transverse section between the atriopore and anus to show the relations of coelom to the atrium.

two sides form the ***oral hood,*** enclosing a funnel-shaped ***vestibule*** leading into the ***mouth***. The buccal cirri and the ***oral tentacles*** are covered by ***sensory cilia*** that set up an inward current of water into the

mouth. The *olfactory pit* is a small depression on the left of the median dorsal fin near the anterior end. The so-called *eye* is a black pigmented area in front of the olfactory pit: it has no cornea, lens or retina. The anterior part of the body is surrounded by the *atrium*. The atrium is a chamber that may be conceived as formed by the side walls of the body extending below and meeting in the middle like the buttoned coat of a man, enclosing a space below the body. The atrium is closed on all sides but opens to the outside by a wide *atriopore* ventrally about the anterior two-thirds of the body The *anus* opens far behind the atriopore.

Alimentary canal.—The *mouth* opens into a large *pharynx*. The side walls of the pharynx are perforated by numerous elongate oblique *gill slits*, opening into the atrium. Behind the pharynx the alimentary canal extends as a straight tube to the anus. In front of the atriopore the alimentary canal has a finger-like *hepatic caecum* on the right side. This functions as the liver. The dorsal wall of the pharynx has a deep *hyperbranchial groove*, lined by cilia. A ventral groove of the pharynx, the *endostyle*, is lined by columnar epithelium and secretes a mucus. The current of water containing dissolved oxygen and minute particles of organic matter enters the pharynx and passes out into the atrium through the gill slits. The mucus secreted by the endostyle entangles the minute organic particles and carries them backward into the intestine behind.

Respiratory system.—The respiratory organ consists of the pharynx. The gill slits are oblique holes on the side wall of the pharynx. The slits are separated by *gill bars*, strengthened by skeletal rods. Each gill bar is richly supplied by blood capillaries. The current of water that passes out of the pharynx into atrium serves as the respiratory current. The capillaries exchange the carbon dioxide of the blood for the oxygen of the water and the exhausted water escapes to the outside through the atriopore.

Circulatory system.—There is no definite heart but the ventral aorta functions as the pulsatory organ. The blood from the alimentary canal and posterior part of the body collects into the *subintestinal vein* below the intestine. This vein enters the hepatic ceacum and breaks up into capillaries within its substance. The capillaries reunite to form *hepatic vein* that runs a short distance backward and then turns forward as the *branchial aorta* below the pharynx. The branchial aorta contracts rhythmically from behind forward and functions as the heart. It gives off lateral branches to the gill bars. These branches break into capillaries in

the gill bars and facilitate the oxygenation of the blood. The capillaries reunite to form ***efferent branchial veins*** dorsally. The efferent veins unite into a right and a left ***aorta***, that combine together behind the pharynx into the median ***dorsal aorta***. The blood runs backward in the dorsal aorta exactly as in the frog.

Coelom.– The coelom is complicated in Amphioxus. It is a narrow space lined on the outside by the ***somatopleur*** and on the inside by the ***splanchnopleur***. A ***dorsal coelom*** above the pharynx communicates by narrow canals with the ***subendostylar coelom*** below the pharynx.

Excretory system.—The excretory organs are serial pairs of ***nephridia***, resembling those of the Annelid but lacking a ciliated nephrostome opening into the coelom. They are arranged on either side of the pharynx in the dorsal coelom. Each consists of an ***excretory canal***, expanded above and opening below into the coelomic canal of the gill bars. On the dorsal surface there are numerous ***solenocytes*** or pin-shaped bodies, containing a wavy flagellum within. The excretory products pass by osmosis into the solenocytes and are propelled by the action of the flagella down into the gill bars. From here they pass into the atrium and are expelled by the atriopore.

Skeletal and muscular systems.—There is an endoskeleton comprising the dorsal ***notochord*** that extends the whole length of the body. The notochord projects slightly at the anterior end in front of the mouth. It is surrounded by a thick connective tissue membrane that is continuous with the connective tissue septa of the myotomes. On either side of the notochord are the V-shaped masses of myotomes.

Nervous system.—The nervous system consists of a simple thick-walled ***nerve tube*** above the notochord. Anteriorly the nerve tube expands into the ***cerebral vesicle***, which in young specimens opens to the outside by a ***neuropore*** dorsally. In the adult the neuropore is closed but its site is indicated by the olfactory pit. Paired nerves are given off laterally from the nerve tube to the myotomes and to other parts. As in the frog, a dorsal sensory root and a ventral motor root give rise to the sensory and motor fibres. The two fibres do not however unite into a mixed nerve. There are also no ganglia on the dorsal roots. The first two pairs of nerves are wholly sensory.

Reproductive system.—The sexes are separate. A large series of paired ***gonadal sacs***, appearing to project into the atrium, contain the ***gonads***. The ova and sperms when ripe, pass into the atrium

by the bursting of the body wall, and escape into the sea water by the atriopore. Fertilization takes place outside the body in the water.

Development.—The ovum is ***holoblastic :*** It is minute and undergoes total cleavage. It is ***isolecithal*** or has only a small amount of yolk distributed uniformly throughout the mass of the egg. The cleavage is therefore ***equal*** : the zygote divides completely into two equal halves. This first cleavage is ***vertical*** (Fig. 298). The second cleavage is also vertical but at right angles to the first. Four equally large ***blastomeres*** result from the two cleavages The third cleavage is ***equatorial,***

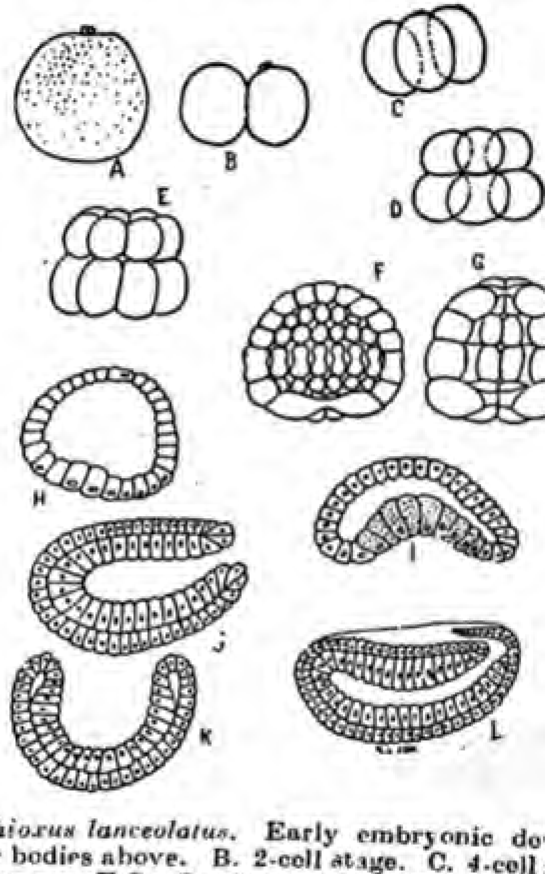


FIG. 298. *Amphioxus lanceolatus.* Early embryonic development. A. Zygote with the minute polar bodies above. B. 2-cell stage. C. 4-cell stage D-E Successive stages in further cleavage. F-G. Sections of blastula. H. Blastula shortly before invagination. I-K. Invagination. J. Gastrula with narrow blastopore. L. Elongated embryo with neural plate and commencement of neurocentric canal. (*Redrawn from Oscar Hertwig, Die Elemente der Entwicklungsgeschichte des Menschen und der Wirbeltiere, Jena Gustav Fischer, after Hatschek*).

so that each of the four blastomeres becomes divided into a slightly smaller upper cell and a slightly larger lower cell. The fourth cleavage divides the eight cells vertically, producing sixteen cells. Repeated meridional and transverse cleavages produce a ***blastula*** enclosing a cavity, the ***blastocoele.*** The blastula is essentially a hollow sphere bounded by a membrane one cell deep. This membrane is the ***blastoderm.***

The cells of the blastoderm on the lower side are somewhat larger than those of the upper side. By unequal growth of the upper and lower parts, the latter becomes tucked inwards or ***invaginated*** into the blastocoele. The invagination increases rapidly so that the blastocoele is obliterated and a double-layered short cylinder results. The new cavity thus produced, i.e. the cavity of the double-layered cylinder is the ***archenteron***, or the primitive gut. The embryo is now a ***gastrula***. The wide mouth of the cylinder is the ***blastopore***. The outer layer is the ***ectoderm*** and the inner the ***endoderm***.

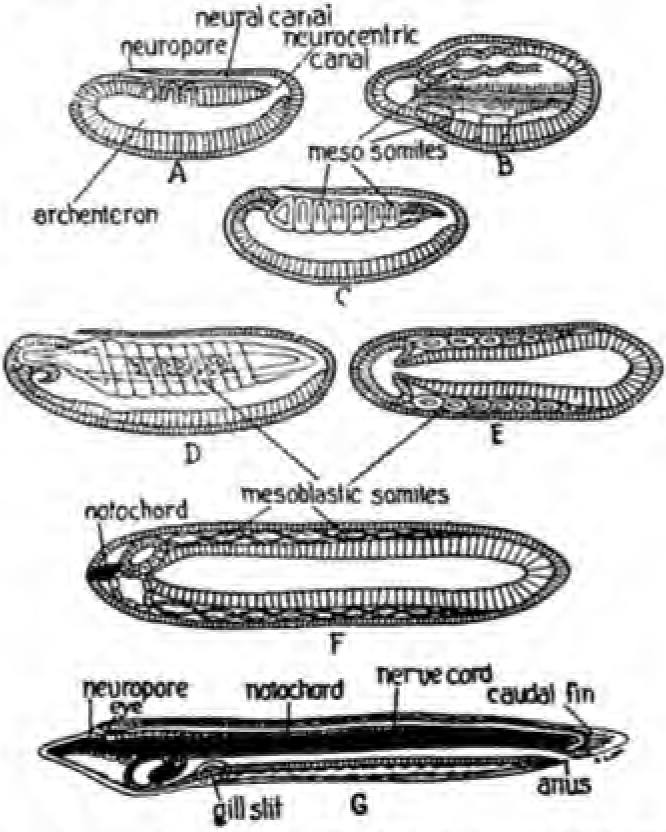


FIG 299. *Amphioxus lanceolatus*. Further stages in development continued from the previous figure. A Sagittal section of embryo with three mesoblastic somites. B. Horizontal section of embryo of the same stage. C. Sagittal section at a later stage. D. Sagittal section of embryo with nine pairs of mesoblastic somites. E. Horizontal section of embryo of the same stage with the head lobes. F. Horizontal section of embryo with fourteen pairs of mesoblastic somites. G Larva, about 36 hours old, with notochord (black), mouth and the first gill slit. (*Redrawn from Hatschek*).

The gastrula soon elongates and the blastopore is narrowed to a small aperture at the end that is later destined to become the posterior end of the adult. One of the long sides becomes flattened : this represents dorsal surface of the future adult. The ectoderm now develops ***cilia*** externally. The embryo begins to rotate within the egg membrane and finally escapes as a free larva.

The ectoderm cells of the flattened side become differentiated as a thick ***neural plate*** (Fig. 300) along the median longitudinal line. The neural plate gradually sinks below the general surface and at the same time the ectoderm cells on either side of the neural plate grow up into ***neural folds***, thus enclosing a ***neural groove***. The neural folds arch over and meet in the middle above the neural groove to form a ***neural tube***, that becomes the nerve tube of the adult. At the same time the ectoderm of the lip of the blastopore grows over the blastopore and continues forward over the neural groove. Thus the archenteron begins to communicate with the neural tube by a narrow ***neurocentric canal***. The closure of the neural groove thus proceeds from behind forward but the groove remains open anteriorly by a small ***neuropore***. The neuropore closes long after the adult stage is reached but its place is indicated by olfactory pit of the adult.

The archenteron produces anteriorly a pair of outpocketings, the ***cephalic vesicles***. The roof of the archenteron develops three longitudinal outfoldings : two lateral and one median. The median fold separates off from the archenteron and becomes compacted into the ***notochord***. The lateral folds become constricted off from the archenteron and form a series of paired pouches, the so-called ***mesoblastic somites*** (Fig. 299), from the front backward, to the right and left of the notochord. The cavity of these somites represents the ***coelom***. The pouches soon enlarge, so that an outer wall, the ***somatopleur*** close to the ectoderm, and an inner ***splanchnopleur*** lying on the endoderm are recognized. These two layers represent the ***mesoderm*** that gives rise to the muscles, blood, blood vessels and the gonads. The wall of the archenteron that now remains is called ***secondary endoderm*** in contradistinction to the primary endoderm when the archenteron is formed. The wall of the archenteron thus gives rise to 1. the notochord and 2. the mass of cells that encloses the coelom and represents the mesoderm. The secondary endoderm forms the inner epithelial lining of the alimentary canal of the adult.

The embryonic development is very rapid ; it is completed within twelve hours after fertilization. The larva soon assumes a fishlike appearance and is peculiarly asymmetrical in many respects. The mouth forms on the left side of the body and the first gill slits open ventrally but soon shift to the right side of the body. These are the ***primary gill slits***. Dorsally above these appear six ***secondary gill slits*** and push then to the left side. The mouth now shifts

from the left to the end of the pharynx. The development now slows considerably and the larva takes several months before it gradually grows into the adult.

Affinities.—Amphioxus is clearly a Chordate. It has been traditionally considered in text-books as a primitive or ***ancestral*** Chordate. Now-a-days it is correctly recognized as greatly specialized in some but highly ***degenerate*** or ***simplified*** in other characters.

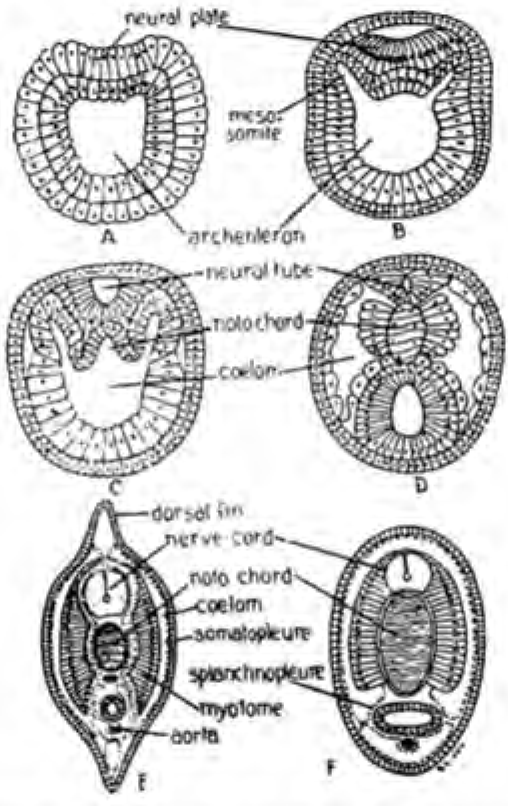


FIG. 300. *Amphioxus lanceolatus.* Transverse sections of embryos at different stages of development, to show the formation of the neural tube, notochord, mesoblastic somites and the coelom. A Embryo with the commencement of the neural groove. B. With the commencement of neural tube, notochordal plate and mesoblastic pouches. C. With neural tube and later stage in the formation of notochord and somites. D. With neural tube and coelom complete. Muscle plates on either side of notochord. E-F. Embryo with muscle segments and blood vessels. (*Redrawn from Oscar Hertwig after Hatschek*).

VERTEBRATA

The Vertebrata differ sharply from the Protochordata in several respects but exhibit the true essential chordate characters.

The notochord appears in the course of the embryonic development, but becomes surrounded by a series of separate structures called ***vertebrae.*** The vertebral column more or less completely replaces the notochord in its function as the chief axial endoskeleton of the

body. There are generally *two pairs* of appendages such as ***fins*** or ***limbs.*** All vertebrates possess a ***heart*** situated ventral to the digestive tract. The heart has *at least* two chambers. The blood contians erythrocytes in which haemoglobin is present. The brain of all vertebrates contains five hollow spaces. Vertebrates also have a posterior prolongation of the body behind the anal opening, forming a ***tail***, which may be long or very short and vestigial. The vertebrate plan of body build is represented diagramatically in fig. 299.

The *digestive system* of the Vertebrates is built more or less on the same plan as in the frog. The digestive system of different vertebrates presents many modifications but the following parts are generally recognized. Mouth, buccal cavity, pharynx, oesophagus, stomach, small and large intestines, rectum and anus. Liver and pancreas are always present and many vertebrates have salivary glands also.

The *circulatory system* includes a central ***heart,*** which receives the blood returning from the tissues and in many cases also from the lungs. It pumps the blood either to the body, gills or to the lungs. Circulation is of the closed type with capillaries.

Respiration takes place in the gills or in lungs. A voice box is also present in many.

The *excretory* organs are two ***kidneys,*** with ducts leading from them. Many have also urinary bladder.

The *nervous system* is essentially as in the frog.

The *skeletal system* is also built essentially as in the frog in many and comprises an axial skeleton with skull and vertebral column, girdles and appendicular skeleton of fins or of limbs. The gills are supported by arches of skeleton ; some of the anterior arches become jaws.

The *sexes* are always separate except in certain hagfishes. The oviducts are not directly connected to the ovaries. In many the fertilization is internal and the embryo develops within the mother more or less.

The Vertebrata are subdivided as follows :

Subphylum I. AGNATHA. Without jaws and paired appendages.

Class 1. OSTRACODERMI. Extinct armoured fishes.

Class 2. CYCLOSTOMATA Body cylindrical, without scales, mouth suctorial, nasal opening single. Example : *Petromyzon* (Fig. 301).

Subphylum II. GNATHOSTOMATA. One pair of gill arches modified as biting jaws. Nasal opening paired. Generally with paired appendages.

Superclass i. *PISCES.* Fishes with paired fins. Skin usually covered by scales Nasal capsule not opening into the buccal cavity. Heart with a single auricle.

Class 1. CHONDRICHTHYES. Cartilagenous fishes, with notochord persistent throughout life. Examples: Sharks and rayfishes.

Class 2. OSTEICHTHYES. Bony fishes; gills covered by operculum. Examples: most fishes.

Superclass ii. *TETRAPODA*. Four-limbed terrestrial vertebrates, typically with five digits. Nasal cavity opening into the buccal cavity; air-breathing; heart with two auricles.

Class 1. AMPHIBIA. Skin moist. Heart with three chambers. Larvae aquatic. Examples: Frog, toad.

Class 2. REPTILIA. Skin dry and usually covered by scales. Heart imperfectly four-chambered. No aquatic larva. Examples: Lizards, turtles and snakes.

Class 3. AVES. Warm-blooded, heart completely four-chambered, body covered by feathers, fore limbs modified as wings. Examples: birds.

Class 4. MAMMALIA. Warm-blooded, body covered by hairs, heart completely four-chambered, females with mammary glands for suckling the young with milk. Examples: mammals.

Resumé

1. The Chordata are bilaterally symmetrical, metamerically segmented animals that possess an axial endoskeleton of elastic notochord, a tubular nervous system dorsad of the alimentary canal and pharyngeal gill clefts. The closed circulatory system comprises a ventral heart and a dorsal aorta.

2. In many Chordata the notochord is replaced by a vertebral column. Jaws and a distinct head develop.

3. The Chordata include all the Vertebrata and some Invertebrata. They are divided into Hemichordata, Urochordata, Cephalochordata and Vertebrata.

4. The first three groups constitute the Protochordata. Protochordates lack cranium, jaws, vertebrae and paired appendages. They include such forms like the sea squirts, amphioxus, etc.

5. The Vertebrata possess a vertebral column, paired appendages, jaws and cranium. They comprise the Ostracodermi, Cyclostomata, Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves and Mammalia.

CHAPTER XVIII

PISCES ПИСЕС

1. CHONDRICHTHYES—THE ~~SHARK, DOGFISH~~

The CHONDRICHTHYES (*chondros*=cartilage, *ichthyes*=fish) represent the lowest living Vertebrates. They include the sharks, rays and chimaeras.

Characters.—

1. Skin covered by minute placoid scales and rich in mucous glands.
2. Median and paired fins are present. They have cartilagenous supporting skeleton.
3. Mouth armed with many teeth.
4. Nasal cavity not connected with buccal cavity; nostrils used only for olfactory and not for respiratory purpose.
5. Skeleton cartilagenous, with persistent notochord.
6. Two-chambered heart, containing only venous blood.
7. Gills 5 to 7.
8. Cold blood.
9. Sexes separate.

Sharks or dogfishes are common all over the world. Most of them are about two to three feet long. Some like the whale-shark, *Rhinedon typus*, measure fifty feet. The common shark of India is *Scoliodon* (formerly *Carcharius*). All are carnivores or scavangers. Some of them are eaten by the poorer folk in India and extensively in China and Japan. Shark-liver oil is a source of vitamin A. Sharks often attack and kill bathers and fishermen.

Classification.—

Class CHONDRICHTHYES.

Order 1. CLADOSELACHII. Extinct sharklike forms. Example : *Cladoselache*.

Order 2. PLEURACANTHII Extinct. *Pleurocanthus*.

Order 3. STEGOSELACHII. Extinct. *Cratoselache*.

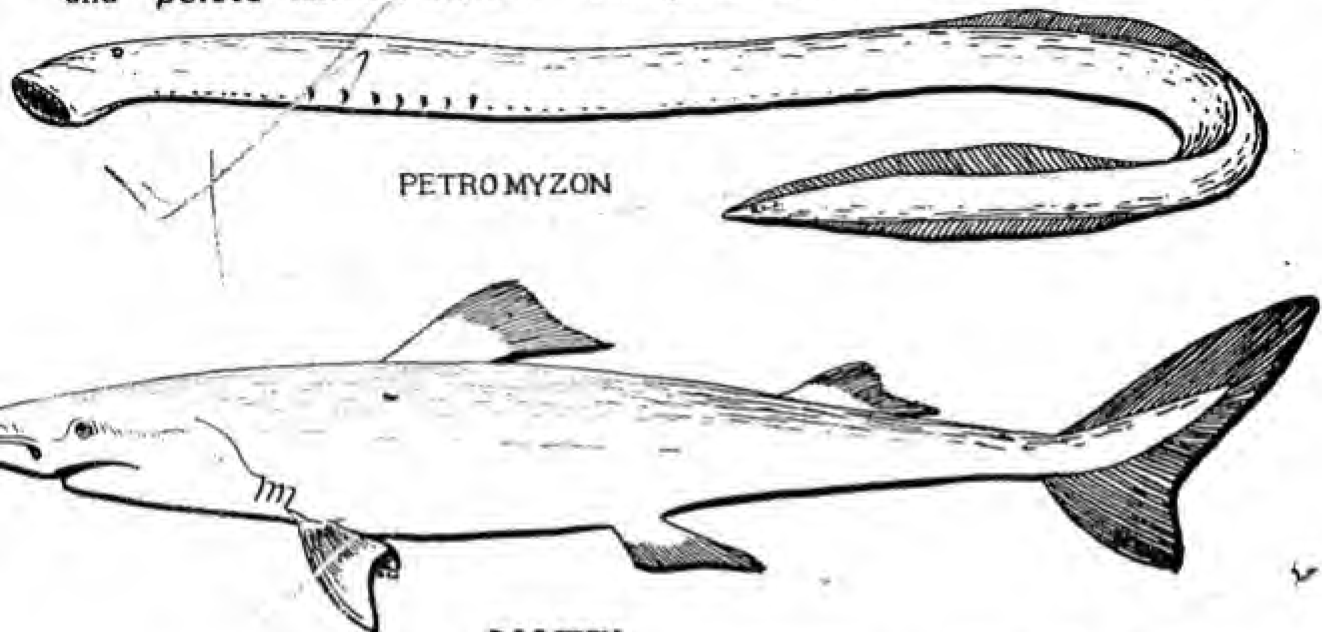
Order 4. SELACHII. Sharks and rays; spiracle behind each eye; gills in separate clefts; cloaca present.

Suborder i. SQUALI. Sharks with compressed body; tail heterocercal; gill slits 5-7 pairs and lateral; pectoral fins not greatly enlarged; first dorsal fin in front of the pelvic fins. Examples : *Scoliodon* (=*Carcharius*) sharks, (Fig. 301) *Sphyrna* hammer-head (Fig. 303), *Rhinedon* whale-shark, *Squalus* and *Acanthias* spiny-dogfishes.

Suborder ii. BATOIDEA. Rayfishes; with depressed body; enlarged pectoral fin joined to sides of head; 5 pairs of gill slits ventral; functional spiracle. Examples : *Raja* sawfish (Fig. 302), *Torpedo* electric ray, (Fig. 304) *Aetobatus* sting ray.

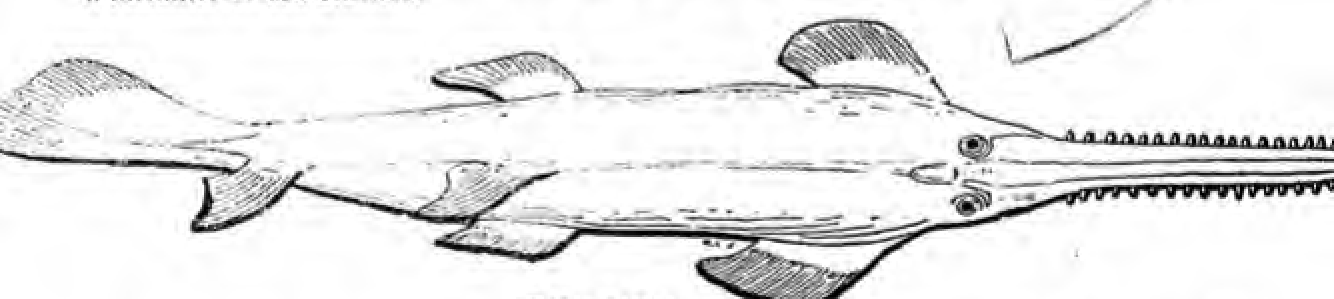
Order 5. HOLOCEPHALI. Chimaeras; gill slits covered by operculum; lack spiracle and cloaca. Example : *Chimaera*.

External features.—The dogfish (Fig. 301, 305) has a perfectly stream-lined body as an adaptation for aquatic life. The body is compressed and the head is flat and bluntly pointed. There are two ***median dorsal*** fins and a ***median ventral*** fin or ***anal*** fin. Paired ***pectoral*** and ***pelvic*** fins are lateral. The pelvic fins are close together and



DOG FISH

FIG. 301. Phylum Chordata. Class Cyclostomata. Petromyzon is an eel-like form commonly mistaken for a fish. The skin is scaleless and slimy. The circular mouth is beset with horny teeth. There is a row of gill openings on either side of the body. Class Chondrichthyes: Dogfish shark is a cartilagenous fish. It is often a menance to sea-bathers.

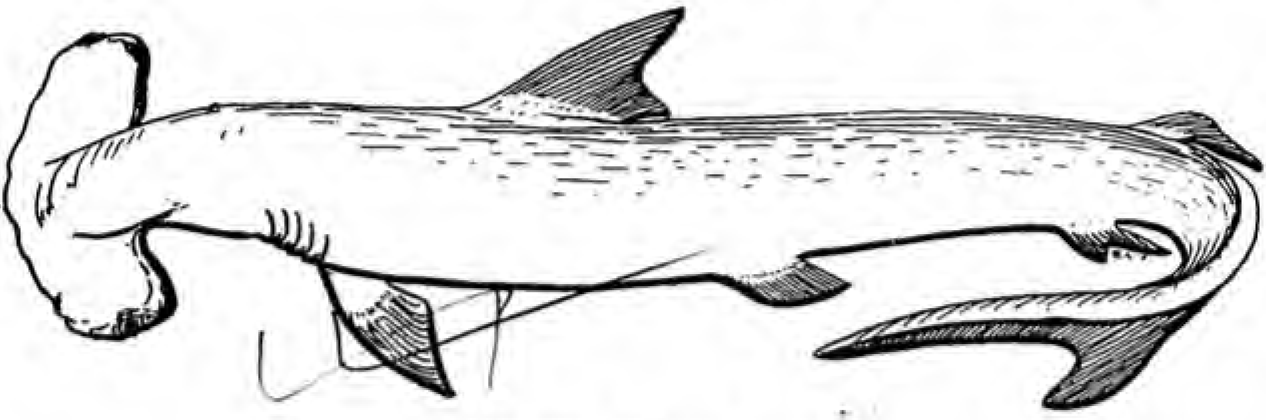


SAW FISH

FIG. 302. Phylum Chordata. Class Chondrichthyes Sawfishes often grow to enormous sizes and their "saws" may attain a length of 6 ft. By means of side-to-side sweeps of their saws, they create havoc among the shoals of fishes which from their food.

small in the female. The male has pair of ***myxipterygium*** or copulatory claspers, which are stiff cartilagenous rods used in mating. All fins point backwards and are used in locomotion. There is in addition an unpaired median ***caudal fin,*** which ***heterocercal***, *i. e.*, the dorsal lobe is larger than the ventral.

The mouth is a wide transverse opening ventrally on the ***snout,*** with inwardly directed sharp teeth. The nostrils are ventral and do not



HAMMER HEADED SHARK

FIG. 303. Phylum Chordata. Class Chondrichthyes. The hammer-headed shark is unique among fishes in having the head produced on each side into a great outgrowth that bears the eyes at the ends.

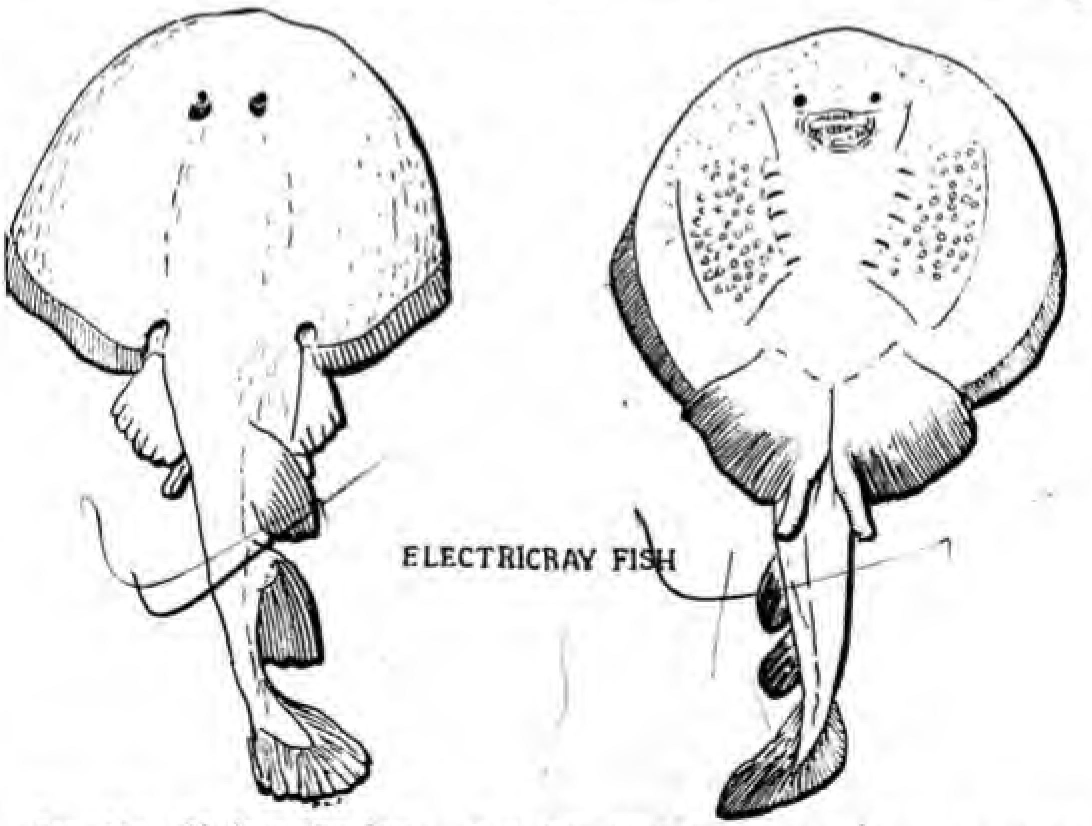


FIG. 304. Phylum Chordata. Class Chondrichthyes. Torpedo or the electric rayfish is capable of giving severe shocks.

communicate with the buccal cavity. The eyes have immovable lids but are provided with nictitating membranes. Five oval ***gill clefts*** open on either

side. Behind each eye is a ***spiracle.*** The anus is situated between the pelvic fins. ***Placoid scales*** are imbedded in the skin. A placoid scale comprises a flat tridentate spine (Fig. 305) projecting backward from a base. The scales become modified into teeth in the jaws.

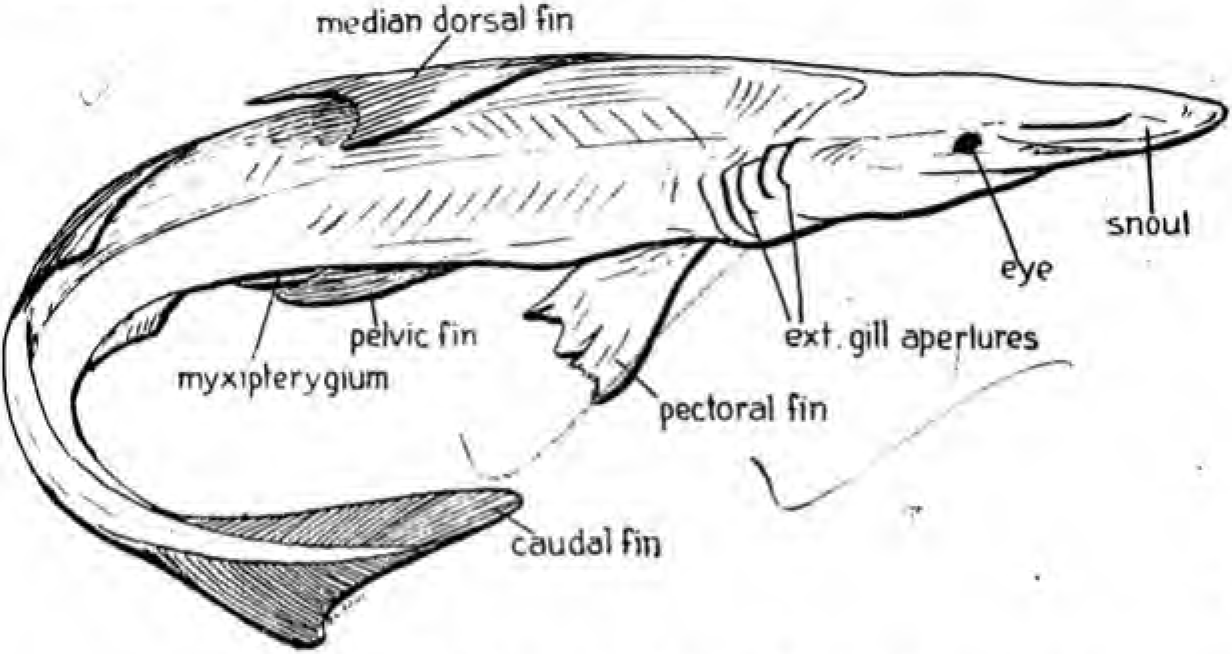


FIG. 305. *Scoliodon*. External features.

Internal organization.—The alimentary canal includes a buccal cavity leading behind to the pharynx, a short oesophagus, a J-shaped stomach, a straight intestine and a rectum ending in the cloacal opening. The mucous membrane lining the inner surface of the intestine is rolled longitudinally upon itself to form the ***spiral valve*** (Fig. 306). This

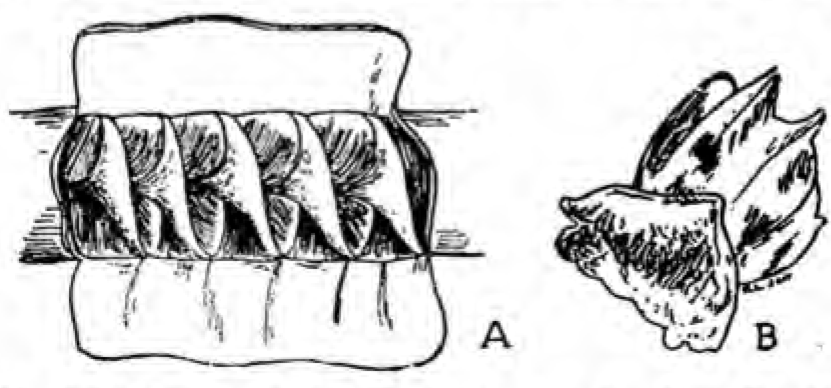


FIG. 306. A. Intestine of *Scoliodon* cut open to show the spiral valve. B. Placoid scale.

valve retards the too rapid passage of digested food and thus helps absorption. The liver is bilobed. There is a small gall bladder. A bilobed pancreas lies in the bend of the stomach.

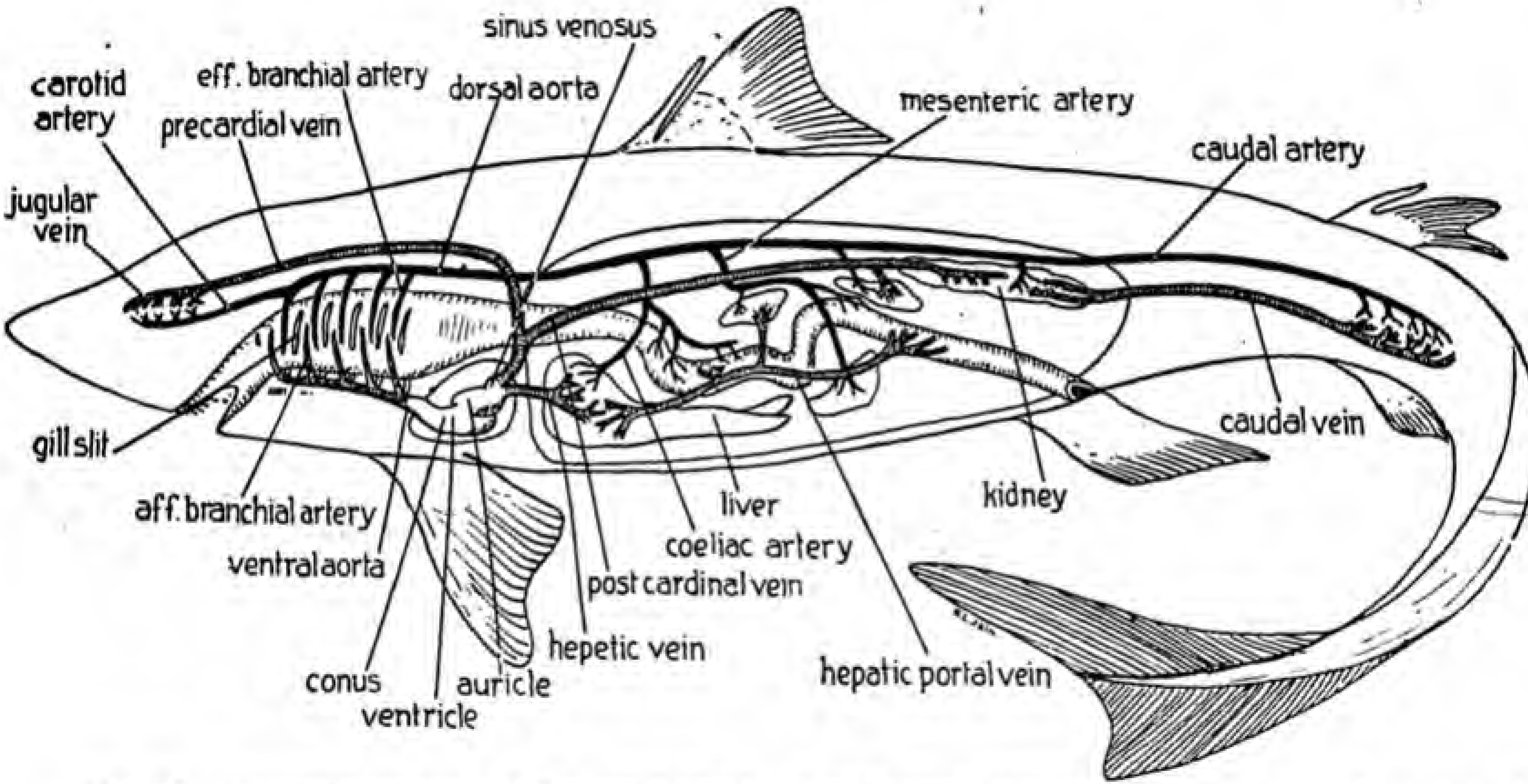


FIG. 307. The circulatory system of *Scoliodon* in lateral view from the left. Veins and ventral aorta striped, arteries and dorsal aorta black. (Read *precardinal* vein for precardial vein.)

The *circulatory system* comprises 1. ***sinus venosus***, 2. two-chambered ***heart***, 3. ***afferent branchial arteries***, 4. ***efferent branchial arteries***, 5. ***dorsal aorta*** and 6. ***veins***.

The sinus is a thin-walled bag. The heart differs from that of the frog 1. in having only two chambers and 2 in containing *only* venous blood. It is thus "a ***branchial heart***" and pumps the blood only to the gills and not to the body direct. The chambers of the heart are 1. an ***atrium*** or auricle in front of the sinus and 2. the ***ventricle*** with thick muscular walls, lying below the atrium. The atrium opens by the atrio-ventricular aperture into the ventricle.

The ***conus arteriosus*** extends from the ventricle. There are two rows of three semi-lunar valves. The conus continues as the ***ventral aorta*** below the pharynx and bifurcates into the ***innominate*** arteries. The innominate artery gives off the first and second and the ventral aorta gives off the third, fourth and fifth ***afferent branchial*** arteries to the gills for oxygenation. The capillaries reunite in the gills to form the ***efferent branchial*** arteries, which unite into ***epibranchial arteries***. The epibranchial arteries run backward and inward to unite and form the ***dorsal aorta*** that supplies fresh blood to the body. The dorsal aorta runs the entire length of the body below the vertebral column and continues as the ***caudal artery*** in the caudal fin. A ***subclavian*** artery from the dorsal aorta goes to the pectoral girdle and a ***coeliacomesenteric*** to the viscera.

The venous system includes 1. ***anterior cardinal*** veins from the head 2. ***posterior cardinal*** veins from the kidney and dorsal body wall, 3. ***hepatic portal*** system and 4. ***ventral veins*** mainly from the paired fins. These veins enter large sinuses connected to the sinus venosus.

The shark draws the water into the mouth and forces it out of the gill slits. The gills are enclosed in the gill pouches and are composed of numerous parallel ***filaments*** containing capillaries. The kidneys are long and extend from the liver to the cloaca. The hinder part is thickened and is the excretory organ proper; the anterior region conveys the genital products.

The testes are paired elongate bodies, united together behind. Several ***vasa efferentia*** from the testes open into the kidneys; the sperm leaves by the cloaca. The ovaries are not directly connected to the outside. The oviducts enlarge into the ***uterus***, unite and open by a slit-like aperture into the urinogenital sinus ending in the cloaca. Fertilization is internal and embryos develop in the uterus.

The skeletal system comprises the axial, visceral and appendicular portions. The skeleton is composed of cartilage or calcified catilages but is never ossified. The axial portion includes a cranium and vertebral column.

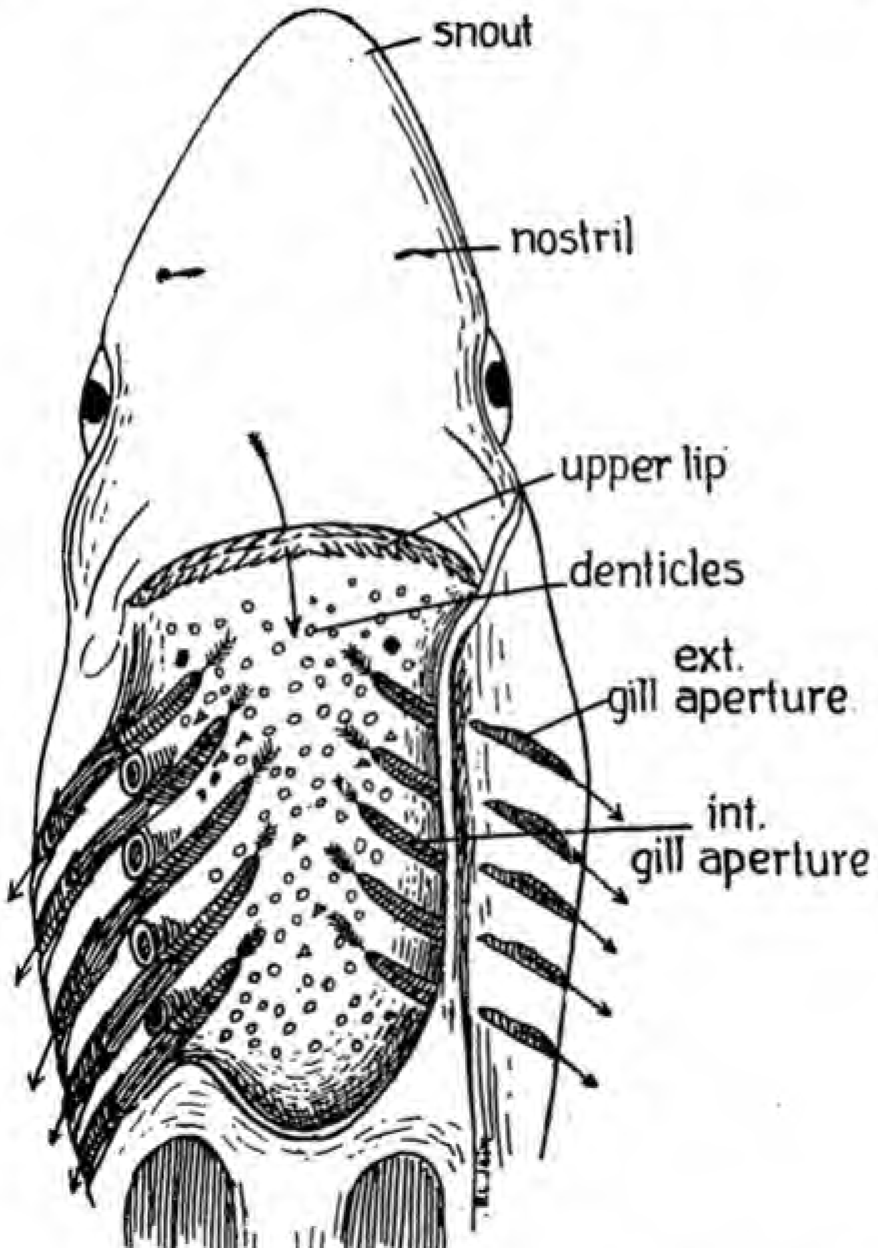


FIG. 308. Dogfish *Scoliodon* in ventral view, with the mouth cavity cut open to show the gill apertures The arrows indicate the course of the respiratory currents.

The visceral skeleton includes a series of seven paired cartilagenous ***visceral arches*** encircling the buccal cavity and pharynx. The first or ***mandibular arch*** gives rise to the jaws; the second is the ***suspensorium*** or ***hyoid arch*** and the rest support the gills and are ***branchial***

arches. The mandibular arch is composed of 1. an upper ***palato-pterygo-quadrate*** and 2. a lower ***Meckel's cartilage***. The palato-pterygo-quadrates of the two sides form the upper jaw. The anterior ends of the palato-pterygo-quadrates of the two sides are joined together by ligaments. The Meckel's cartilages extend along the posterior margin of the mouth and unite to form the lower jaw. Posteriorly the mandibular arch is suspended from the cranium by the upper members of the hyoid arch. This has three segments: a dorsal ***hyomandibular***, a lateral ***ceratohyal*** and a ventral ***basihyal*** It is the hyomandibular which forms the suspensor apparatus for the lower and upper jaws and is therefore called the ***suspensorium***. The skull in which the hyomandibular forms the suspensorium is described as ***hyostylic***. The hyomandibular and the ceratohyal form the anterior wall of the first gill cleft and carry branched ***gill-rays*** along their posterior borders.

The *appendicular* portion includes the skeleton of the median and paired fins and of the pectoral and pelvic girdles. The skeleton of the two dorsal and median ventral fins consists of a series of cartilagenous rods—***somactidia*** or ***pterygiophores***, bearing distally the fin rays, ***ceratotrichia***. The first dorsal fin has twenty-one somactidia The neural and haemal spines of the verteberal column are elongated and flattened to support the dorsal and ventral lobes of the caudal fin.

The pectoral girdle is behind the last branchial arch. It comprises two halves, fused in the mid-ventral line but free above. The ventral half of each arch is the ***coracoid*** and supports the pericardial cavity ; the dorsal rod-like piece is the ***scapula***. The pectoral fin is composed of basal ***propterygium***, ***mesopterygium*** and ***metapterygium*** and a large number of segmented ***radials***. The pelvic fin skeleton consists of a curved basal ***basipterygium***, articulating anteriorly with the very poorly developed pelvic girdle It includes fifteen radials on the outer border of basipterygium The radials bear ceratotrichia.

The *nervous system* is essentially as in the frog, but the proportions of parts differ. The cerebrum is undivided. The olfactory lobes are large. The cerebellum is well developed. There are ten pairs of cranial nerves and one pair of terminal nerves. The paired spinal nerves arise by two roots. The sense organs are the ***olfactory sacs*** on the snout, the eyes, the ears and ***lateral line canals***.

The dogfish is of great interest because its structural features appear in the early stages of the embryonic development of higher vertebrates.

2. OSTEICHTHYES—BONY FISH

Characters.—

1. Skin generally covered by scales.
2. Both median and paired fins generally present.
3. Mouth with jaws and teeth.
4. Olfactory sac not communicating with the buccal cavity.
5. Skeleton mainly bony.
6. Heart branchial, two-chambered. Aortic arches four pairs.
7. Blood with nucleated red corpuscles.
8. Respiration by gills. Air bladder often present.
9. Sexes separate.

Neopter...

Classification.—

Class OSTEICHTHYES

Subclass i. *PALAEOPTERYGII.* Ancient and primitive fishes, with fin rays of dorsal and anal fins more numerous than their internal skeletal supports.

Order 1. CHONDROSTEI. Naked and scaleless or with ganoid scales; prominent snout; heterocercal tail; skeleton largely cartilagenous. Example: *Acipenser* sturgeon.

Subclass ii *NEOPTERYGII.* Modern fishes, with usually amphicoelous vertebrae; dermal rays and skeletal supports of dorsal and ventral fins equal; caudal fin homocercal; cycloid or ctenoid scales.

Order 2 GINGLYMODI. Ganoid scales, long snout and lower jaw. Examples: Gar pikes.

Order 3. ISOSPONDYLI. Fins lack spiny rays; air bladder opening into pharynx. Examples: *Salmo* salmon, *Clupeus* herring.

Order 4. OSTARIOPHYSI The lateral elements of the first four vertebrae modified as Weberian (auditory) ossicles; air bladder divided into two or three parts and opening into pharynx.

(a) Cyprinoid fishes: *Electrophorus* electric eel, *Cyprinus* carp, *Labeo rohita.*

(b) Siluroid fishes: cat fishes with the mouth armed with sensory barbels, Examples: *Macrones* teng-ga-ra, *Clarias* magur

Order 5. APODES. Elongate, slender; continuous dorsal and anal fins; pelvic fins absent. Example: *Aguilla* fresh-water eel.

Order 6. SYNENTOGNATHI Pectoral fins high up dorsally. Example: Flying fish (Fig. 314)

Order 7. MICROCYPRINI. Small, viviparous fishes. Example: Minnows.

Order 8. SOLENICHTHYES. Body slender and elongate or head at an angle to the body. Male generally with broad pouch containing eggs. Examples: *Syngnathus* pipe-fish (Fig. 314), *Hippocampus* sea-horse. (Fig. 313).

Order 9. PERCOMORPHI. Bony, spiny and soft fin rays present in dorsal and anal fins. Examples: *Perca* perch, Gobies, *Mugil* mullets.

Order 10. HETEROSTOMATA. Asymmetrical flatfishes with both the eyes on one side; bottom dwellers. Examples: *Pleuronectes* flunder or (Fig. 310) flatfish, *Hippoglossus* halibut.

Order 11. PLECTOGNATHI. Body form varied. Examples: *Diodon* porcupine-fish (Fig. 313), *Mola* sun-fish, *Ostracion* trunk-fish (Fig. 311).

Subclass iii *CROSSOPTERYGII.* Lobe-finned fish. Pectoral fin lobate and articulated; scales if present ganoid.

Order 12. DIPNEUSTI. Lungfish. Air bladder lung-like. Examples: *Protopterus, Neoceratodus.*

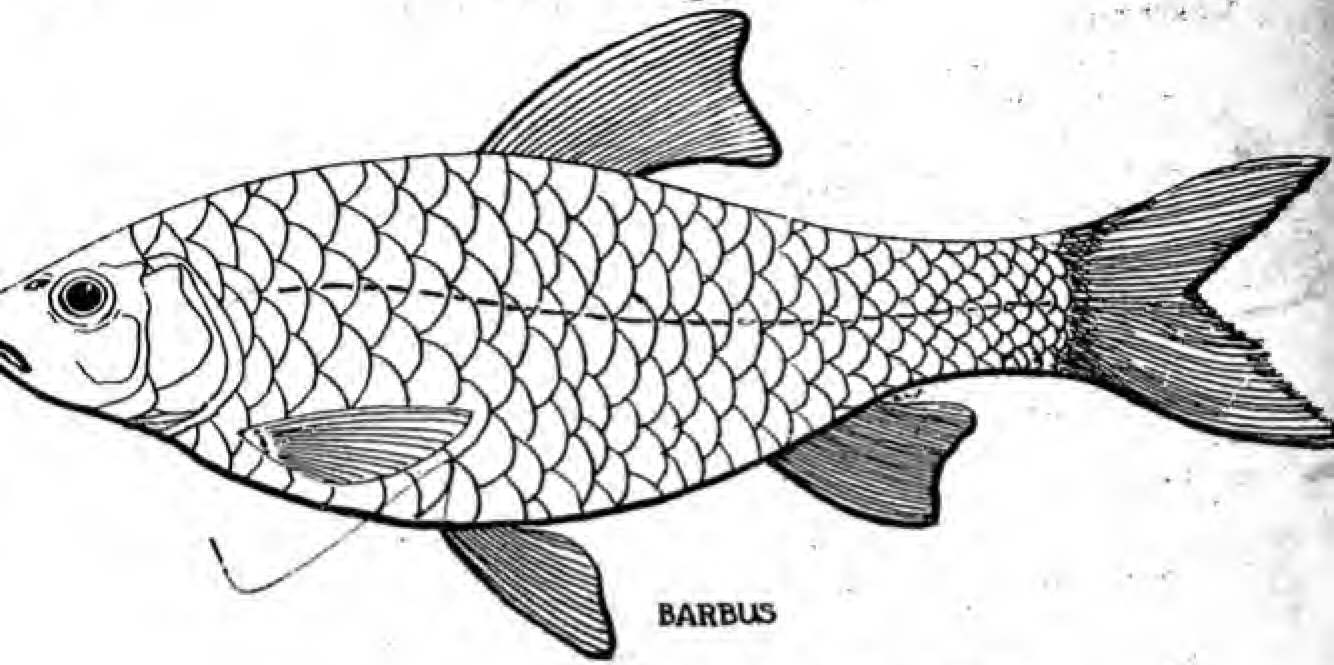


FIG. 309. Subclass Neopterygii. Order Ostariophysi.

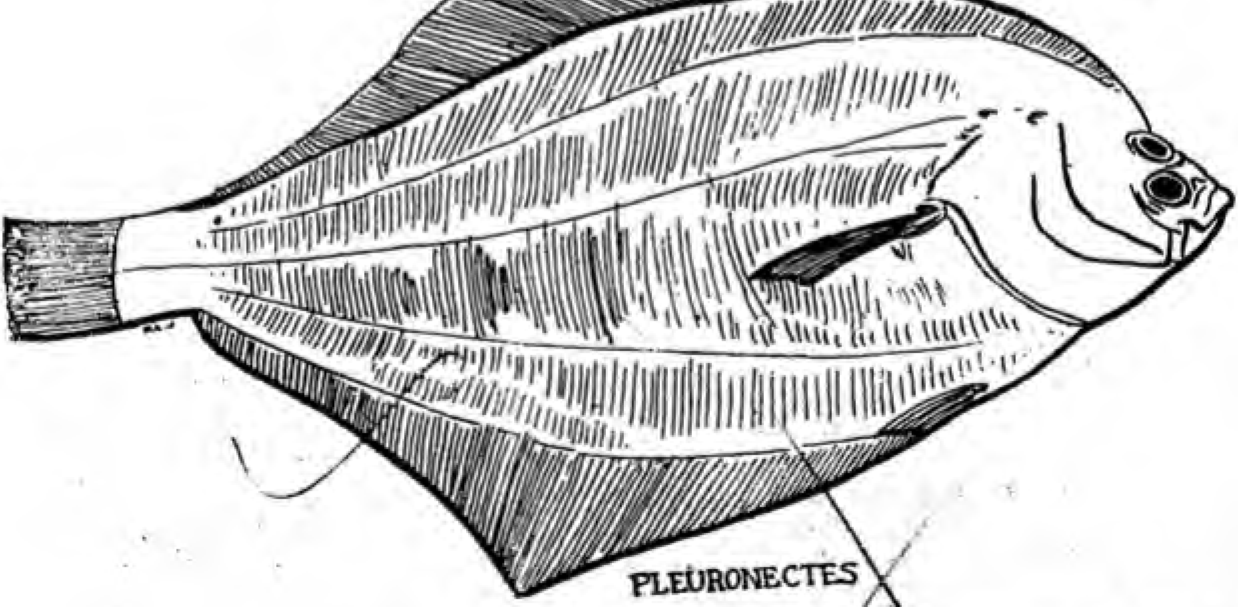


FIG. 310. Subclass Neopterygii. Order Heterostomata. *Pleuronectes*, the flat fish differs from all other fishes in having the eyes on the same side of the head. The flat sides do not represent dorsal and ventral but the right and left sides.

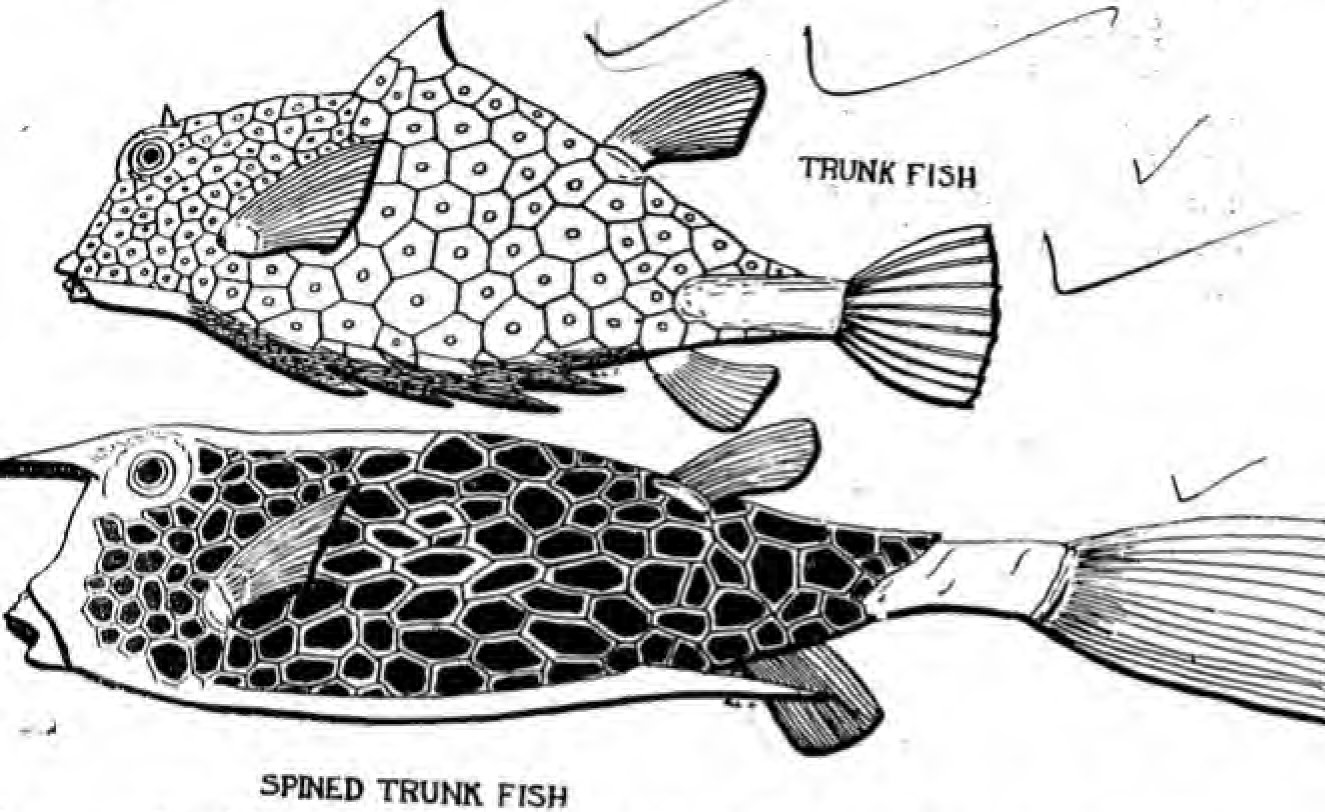


FIG. 311. Subclass Neopterygii. Order Plectognathi. The Indian trunk fishes have specialized in building up a heavy body armour at the cost of speed. The head and body are enclosed in a hard box of hexagonal bony plates and are often spined.

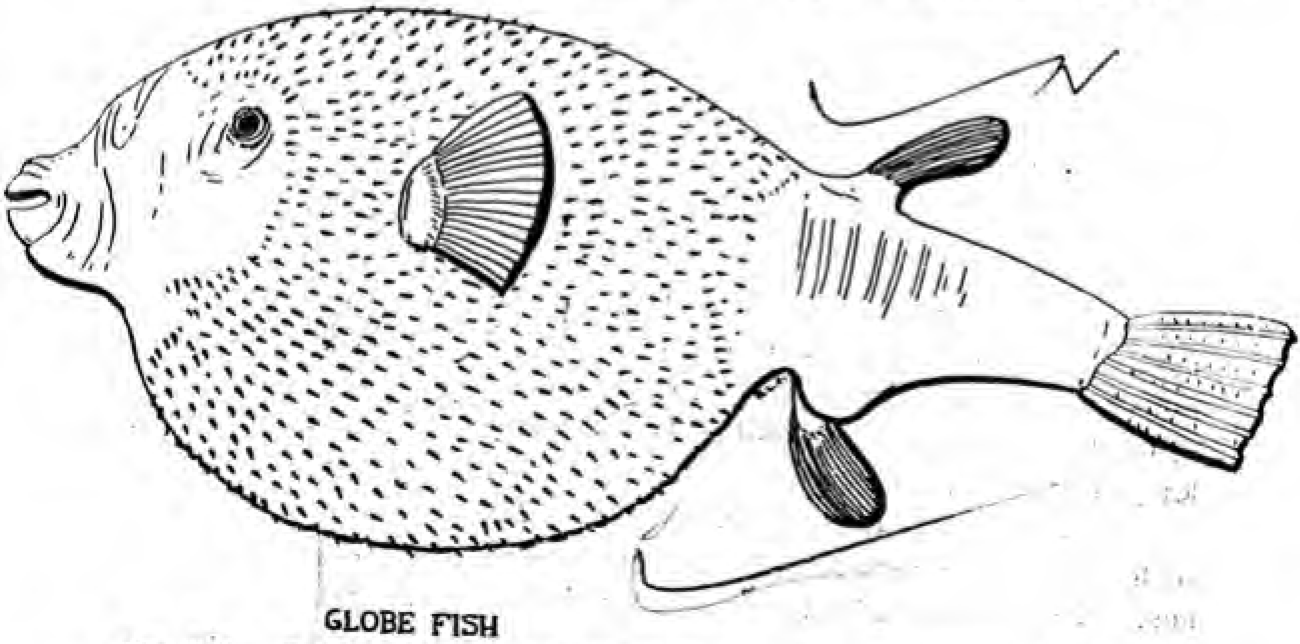


FIG. 312. Subclass Neopterygii. Order Plectognathi. The globofish or puffer is capable of swallowing air or water until the body becomes inflated like a baloon. The spines that cover the skin then stand erect, giving the fish an alarming appearance and scaring away enemies.

Structure.—The body of fishes is stream-lined so as to facilitate cleaving the water in swimming. The scales of the fish are of three types : ***cycloid, ctenoid*** and ***ganoid,*** which usually overlap like the tiles of a roof. The cycloid scales are marked by concentric lines. The ctenoid scales have minute tooth-like points where they do not overlap. The ganoid scales have enamel-like covering and sometimes do not overlap.

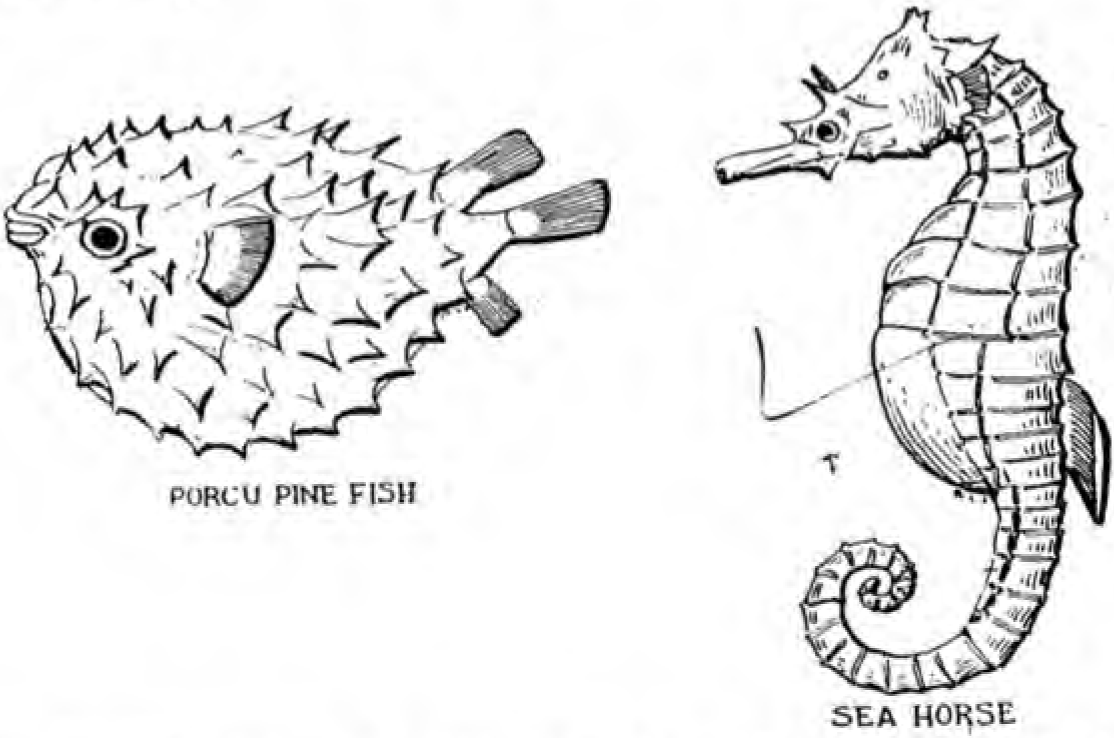


FIG. 313. Subclass Neopterygii. Order Plectognathi. The porcupine fish has habits similar to the globefish. When inflated, the strong spines form a formidable protective armour. Order Solenichthyes. The sea horse is a peculiar defenceless fish that depends for protection upon resemblance to surrounding objects. The young are cared for and the eggs carried in a pouch by the father.

The unpaired fins are the median dorsal, the caudal and the anal. The pectoral and the pelvic fins are paired. The fins are the principal organs of locomotion and aid in maintaining equilibrium. In the flying fish (Fig. 314) the paired fins are large and are used as ***planes*** for gliding in air.

The scales constitute the exoskeleton. The endoskeleton comprises the skull, vertebral column, ribs, girdles and ***pterygophores*** that support the fins. The skull includes the cranium and the ***visceral skeleton.*** The visceral skeleton comprises seven paired ***arches.*** These are homologous with the cartilagenous gill arches of the shark. The first is the ***mandibular arch ;*** its dorsal half, the ***palato-pterygo-quadrate,*** forms the

upper jaw. Round the ventral half, ***Meckel's cartilage,*** the three bones ***dentary, angulare*** and ***articulare*** of the lower jaw are formed. The second is the ***hyoid*** arch and forms a support for the tongue. The following four arches have each a gill. The vertebrae are ***amphicoelous***. In addition to the dorsal ***neural arch,*** each caudal vertebra

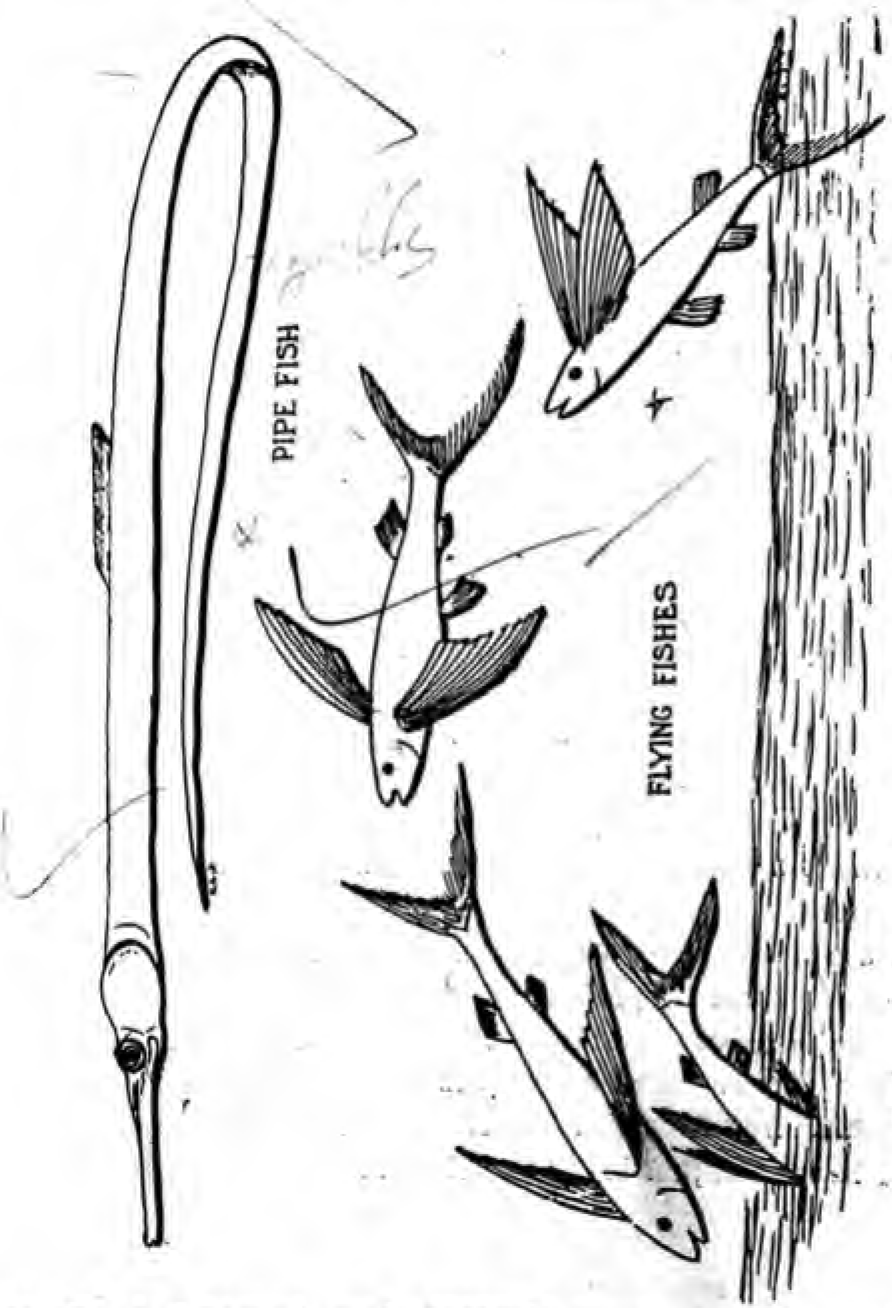


FIG. 314. Subclass Neopterygii. Order Solenichthyes. The pipefish has the snout drawn out into a lengthy tube and the body is also tube-like in appearance. Order Synentognathi. The flying fishes are capable of making flights by means of their enormously enlarged pectoral fins. The fins are not flapped like the wings of a butterfly but act merely as parachutes.

has also a ***haemal arch*** ventrally surrounding the caudal artery and caudal vein. The pectoral girdle is composed of several bones. Segmental muscles or ***myotomes*** alternate with the vertebrae and are separated by delicate septa of connective tissue.

In the buccal cavity small conical teeth are employed in firmly securing any slippery prey and not for chewing. There are no salivary glands but the buccal cavity is rich in mucous glands. The pharynx continues behind as the stout oesophagus, with the stomach close behind. A short coiled intestine leads to the anus. The liver and gall bladder lie in front of the stomach.

The circulatory system is essentially the same as in the shark. It comprises a two-chambered heart, ventral aorta, four afferent and efferent branchial arteries, dorsal aorta and veins.

The gills are the principal respiratory organs. Each gill is composed of a double row of ***gill filaments***. The gills are enclosed in a common gill chamber beneath the ***operculum***. Bony fishes have thin-walled ***air bladder*** (or swim bladder) dorsally in the body cavity. The air bladder is filled with air or gases like oxygen, nitrogen and carbon dioxide. The air bladder serves as an accessory respiratory organ and also as a ***hydrostatic*** organ. In the lungfish (Dipneusti) the air bladder becomes lung-like and is filled with air, that is gulped in by the mouth

Paired kidneys constitute the excretory organs. Paired ureters lead behind into the urinogenital sinus.

The nervous system and sense organs are very much like those of the shark.

Locomotion.—Most fishes swim by the lateral waving movements of the tail and of the caudal fin. The paired fins serve to maintain the balance and in steering—changing direction. The backward ejection of water from the gills acts as a jet propulsion mechanism and thus drives the fish forward.

Food.—Fishes feed upon aquatic plants, small animals or dead and decaying matter. Some are predaceous.

Economic **importance.** - Fishes constitute an important source of human food. Fish oils are used as oil paints, insecticides and medicine. Glue is also manufactured from fish wastes. Some like the top-minnows destroy mosquito larvae and thus aid in malaria control.

RESUME

I. Chondrichthyes

1. The Chondrichthyes include the sharks, rays and chimaeras. They represent the lowest living vertebrates.

2. The skeleton is wholly cartilagenous. The skin is covered by placoid scales.

II. Dog fish

3. *Scoliodon* is the common dogfish shark of India. It is a carnivorous form widely distributed in the tropical seas. It has five pairs of gill slits, paired pectoral and pelvic fins, two median unpaired dorsal fins and one median ventral fin. The caudal fin is heterocercal. The fins serve as locomotor apparatus.

4. The alimentary canal includes a J-shaped stomach and a straight intestine with a spiral valve inside.

5. The circulatory system includes a sinus venosus and a two-chambered heart that wholly contains venous blood, which it pumps only to the gills. The dorsal aorta is the main distributing trunk.

6. The gills are the respiratory organs. Kidneys perform the excretory function.

7. The sexes are separate. Fertilization and development are internal: the shark is viviparous.

8. The nervous system is built on the same plan as in the frog. Olfactory sacs, eyes, ears and lateral line canals constitute the special sense organs

III. Osteichthyes

9. The Osteichthyes comprise mainly the bony fishes. They are divided into the Palaeopterygii, Neopterygii and Crossopterygii.

10. The body is stream-lined as an adaptation for swimming. The scales are either cycloid, ctenoid or ganoid.

11. The gills are enclosed by the operculum. Many have air bladders that serve as accessory respiratory and hydrostatic organs.

CHAPTER XIX

AMPHIBIA

CHANGE FROM AQUATIC TO TERRESTRIAL LIFE

Amphibia.—The AMPHIBIA represent the transition between the aquatic fishes and the terrestrial reptiles. They are equally at home in water and on land. A few are permanently aquatic but the others live in the neighbourhood of swamps, marshes or other bodies of water. They spend their larval life entirely in water.

Characters.—

1. Body mostly naked, not covered by scales, feathers or hairs; skin slimy and moist.
2. No fins. There are two pairs of LIMBS; four or five toes which are often webbed.
3. Paired external nares open into the buccal cavity; nasal cavity used not only in smelling but also in breathing.
4. Ear drums external in frogs and toads.
5. Skeleton largely bony. Occipital condyle two. Ribs absent, if present not articulated to the sternum.
6. Heart three-chambered and with 1—3 pairs of aortic arches; red corpuscles nucleated.
7. Respiration by gills, lungs or skin. Vocal cords in frogs and toads.
8. Body temperature variable.
9. Ferilization external in water; larvae aquatic.

The Amphibia are of great biological interest because in the life-history of many of them are illustrated the modifications in the change from an aquatic to a terrestrial life. The development of the fish-like tadpole for example is a brief and simplified summary of the changes undergone by Vertebrates in the ages past in the course of evolving into land animals.

The change from the aquatic to terrestrial life involves modification of organs of 1. locomotion, 2. respiration, 3. circulation and 4. reproduction.

In water the animal is partly buoyed up by the water but on land the weight of the body has to be actively supported. The fins characteristic of fishes could not function on land. The limbs serve not only to support the body but also to move it from place to place.

The respiratory organ is essentially a thin membrane through which oxygen passes from the water into the blood. Since this membrane must be kept moist, the land animals have entirely different respiratory system

from that of fishes. The lung is essentially a membranous sac enclosed within the body for protection.

The circulatory system shows very important modifications. The heart of the fish contains only *venous* blood. In the Amphibia there are *two* auricles and one ventricle. The oxygenated blood returns to the heart before being distributed to the body.

The Amphibia are not however wholly emancipated from water, because reproduction still takes place in that medium. Fertilization and early development are as in fishes.

The changes in leaving the aquatic habitat for one upon land may be summarized as below :

1. Limbs, 2. lungs, 3. double circulation : pulmonary and systemic, 4. eyes modified for distant vision by flattening of the lens and 5. ear,

Comparison between fishes and amphibians

	FISHES	AMPHIBIANS
1.	Body usually covered by scales	Body not covered by scales
2.	Median and paired fins present	No fins ; 4 limbs (typically with 5 toes)
3.	No external ear drum	External ear drum
4.	Nasal cavity not opening into the buccal cavity ; "nose" serves only for smelling.	Nasal cavity opens into the buccal cavity ; "nose" serves both for smelling and for breathing.
5.	No vocal cords	Vocal cords present in many
6.	No lungs	Lungs present
7.	Heart branchial, pumps blood to the gills ; contains no oxygenated blood.	Heart pumps blood to the gills, skin or lungs and body as well ; contains both oxygenated and venous blood.

The Amphibia originated from extinct CROSSOPTERYGIANS. In the ages past the climate was warm, with heavy rainfalls, often followed by periods of droughts when the water of the ponds dried up. The lobe-finned fishes were thus compelled to migrate overland in search of fresh ponds. Instead of immediately seeking water, some of them lingered more and more on the bank, devouring insects. The lobed fins thus came to be gradually modified into legs and the Crossopterygian fishes became amphibians These early forms are represented by the extinct *Stegocephalia*. In addition to the stegocephalia, frogs and toads, the Amphibia include also the rare legless, burrowing, snake-like Caecilians, lizard-like salamanders and newts.

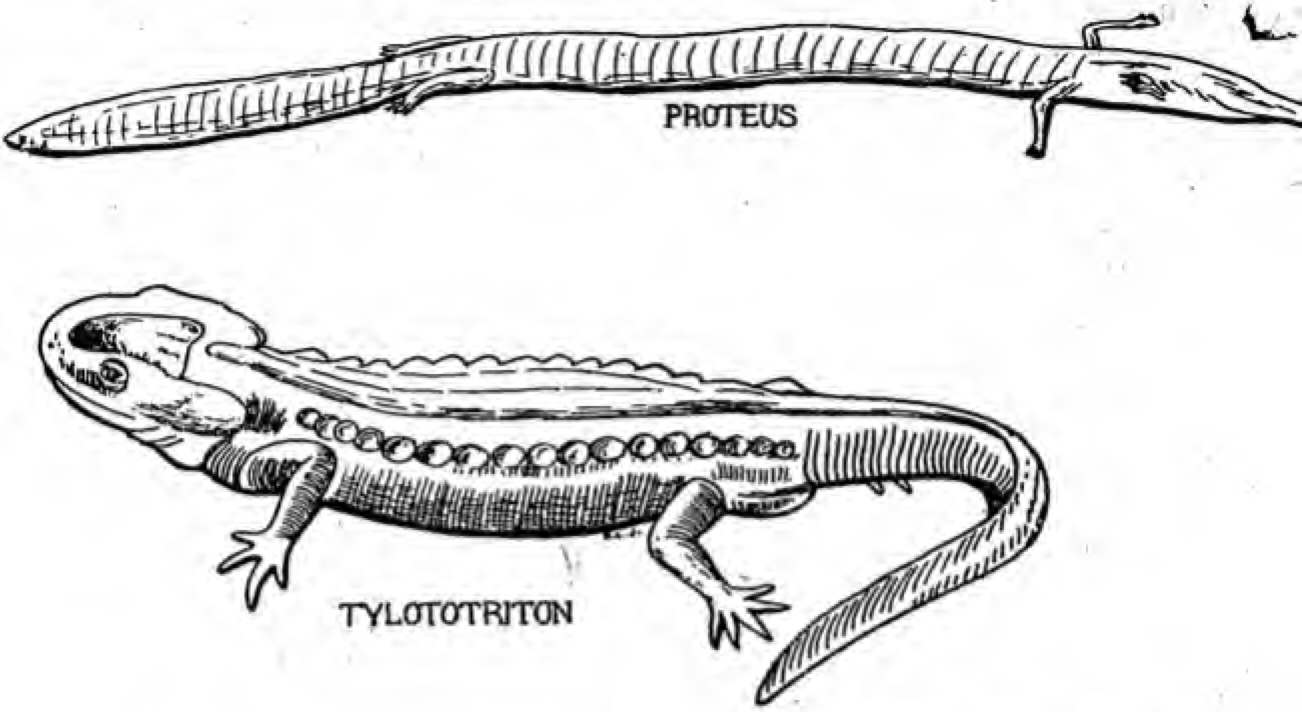


FIG. 315. Amphibia-Urodela. *Proteus* lives in waters of deep caves in Europe and is blind ; its eyes are buried beneath the skin. *Tylotriton verrucosus*, lacks gills in the adult. It occurs in the mountains of Yunnan, Kakhyen Hills, Sikkim. (*After Boulenger*).

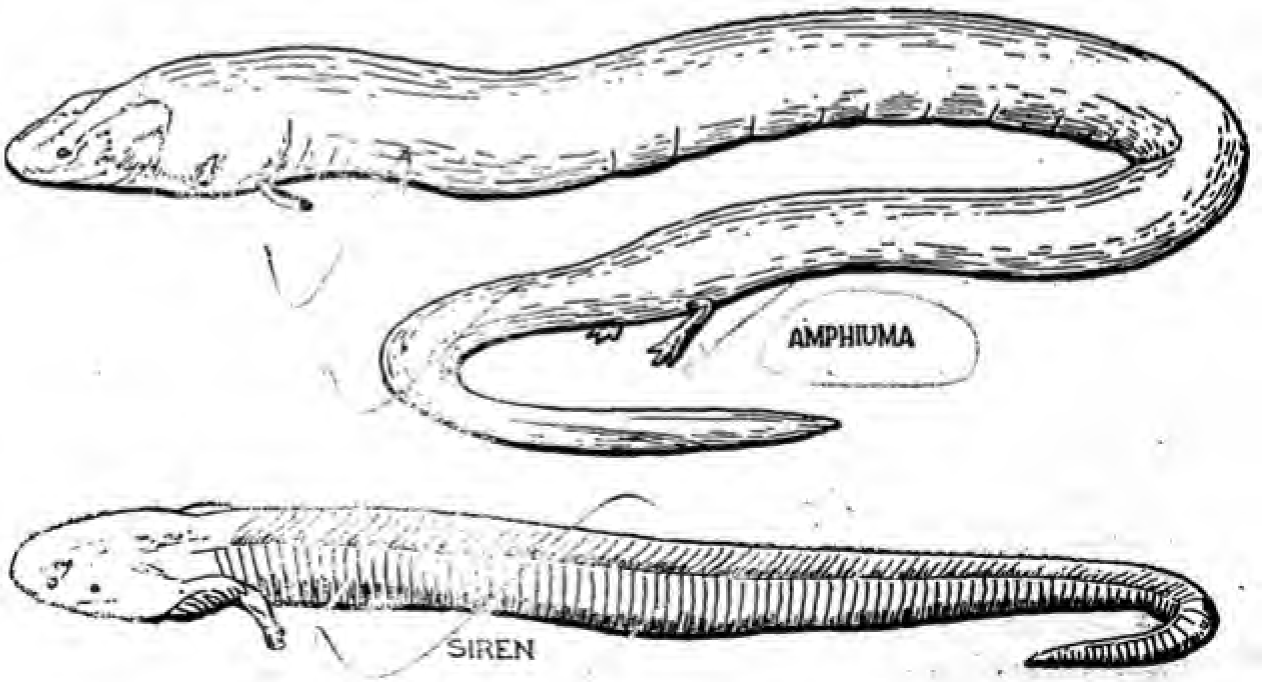


FIG. 316. Amphibia-Urodela. *Amphiuma* the "Congo-eel" occurs in swamps and feeds on small fish, shellfish, etc. *Siren* the "Mud-eel" from America occurs in muddy pools.

Classification.—

Class AMPHIBIA (=Batrachia).

Subclass I. *APSIDOSPONDYLI*

Superorder i. LABYRINTHODONTIA. Large extinct forms ancestral to the reptiles. Example: *Eryops* (Fig. 317).

Superorder ii. SALIENTIA. Tailless forms, without neck; hindlegs for jumping; urostyle present.

Order. Anura. Frogs and toads.

Family 1. Discoglossidae. Old world frogs, with eyelids and disc-shaped but not protrusible tongue. Example: *Discoglossa.*

Family 2. Pipidae. Aquatic frogs without eye-lids and tongue. Example: *Pipa.*

Family 3. Bufonidae. Toads, without maxillary teeth; skin warty. Example: *Bufo* (Fig. 319).

Family 4. Hylidae. Tree-toads, with teeth in maxilla, toes expanded into adhesive discs. Example: *Hyla* (Fig. 320).

Family 5. Ranidae. Frogs. Teeth in maxilla, tongue forked and potrusible. Example: *Rana.*

Subclass II. *LEPOSPONDYLI*

Order i. Urodela. (=Caudata) Salamanders and newts. Body elongate, with a distinct neck and tail; all legs of nearly equal size.

Family 1. Proteidae. Examples: *Necturus* mud-puppy (Fig. 318) from N. America Aquatic. *Proteus* (Fig. 315) in waters of deep caves, blind and colourless.

Family 2. Cryptobranchidae. Example: *Cryptobranchus* from N. America. Permanently aquatic.

Family 3. Amblystomidae. Example: *Amblystoma tigrinum* tiger salamander (Fig. 318) from N. America. Larvae often perennial and known as "axolotl".

Family 4. Salamandridae. Example: *Salamandra* from Europe, Asia and America, with lungs but no gills. Adults terrestrial.

Family 5. Amphiumidae. Example: *Amphiuma* Congo eel, (Fig 316) N. American, in swamps. Cylindrical, without eyelids. with lungs, gills and gill slits.

Family 6 Sirenidae. Example: *Siren* mud eel (Fig. 316), from N. America, in burrows, muddy ditches.

Order ii. Apoda. (=Gymnophiona) Coecilians. Example: *Ichthyophis* (Fig. 317) from India. Slender worm-like, without legs, girdles; skin with transverse furrows; short tail. In burrows in moist ground.

Bionomics.—Amphibia are widely distributed but are most abundant in moist and temperate regions. None is found in the sea. *Necturus*, *Cryptobranchus*, *Amphiuma*, *Siren* and *Pipa* are aquatic. *Hyla* is arboreal. The salamanders and caecilians live in burrows.

The Amphibia cannot tolerate extremes of climate and resort to hibernation during winter and aestivation during summer. During these periods of ***suspended animation***, the bodily activities are slowed down, heart-beat very much retarded and the stored-up reserve of glycogen is gradually utilized.

The midwife toad of Europe carries the strings of eggs on his legs till the tadpoles hatch. *Pipa* carries her eggs in pockets on her back.

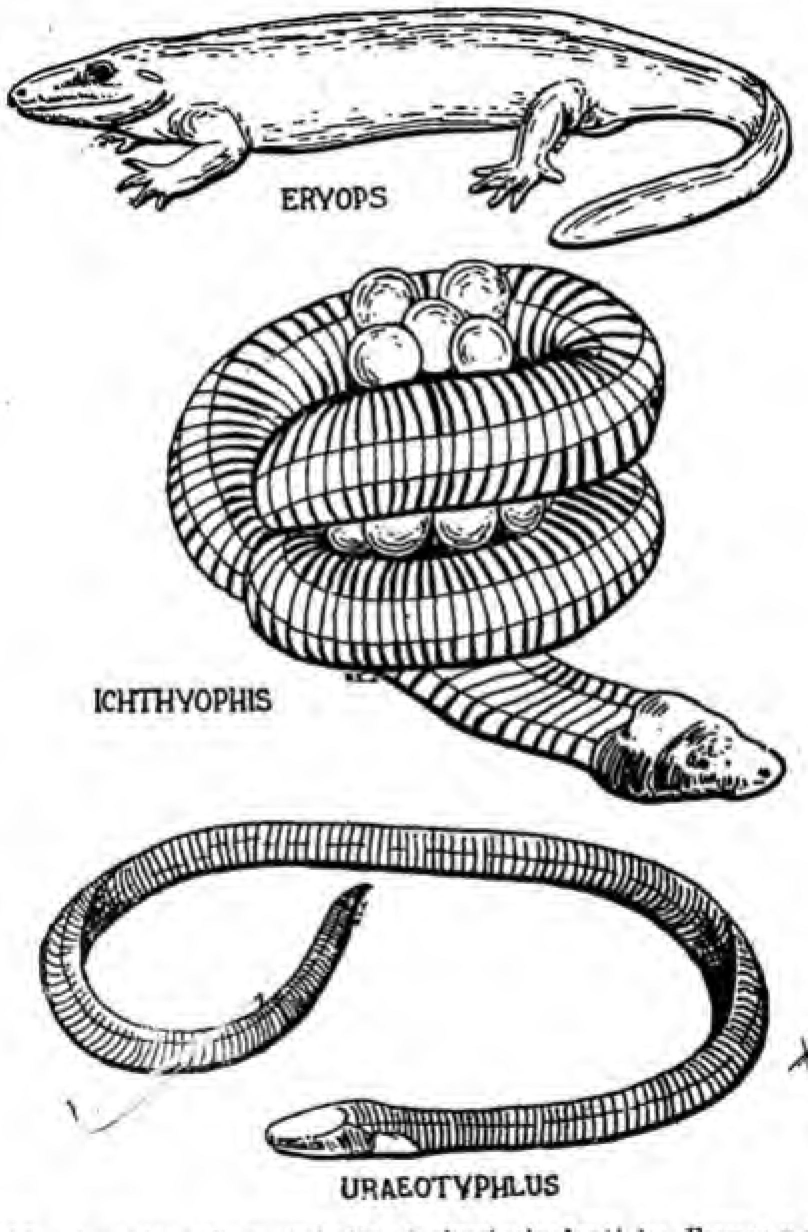


FIG. 317. Amphibia-Stegocephalia : Labyrinthodonti A : *Eryops* a crocodile-like fossil amphibian 9 ft long. Gymnophiona (Apoda) : *Iohthyophis glutinosus*. The female constructs a burrow in soft mud leading from a pond. She lays eggs in this burrow, coils herself round and guards them. It occurs in the mountains of Ceylon, Malabar, Eastern Himalayas, Burma, Siam, Malaya, Sumatra, Borneo and Java (*After Sarasin*). *Uraeotyphlus oxyurus* occurs in Malabar. Small cycloid scales are imbedded in the skin. Body cylindrical.

The amblystomas are of great interest. They give rise to perennial larvae, that live for over twenty years, reach adult size and even breed. Reproduction by a larva is called ***paedogenesis***. The condition in which the larva becomes sexually mature, without metamorphosing into

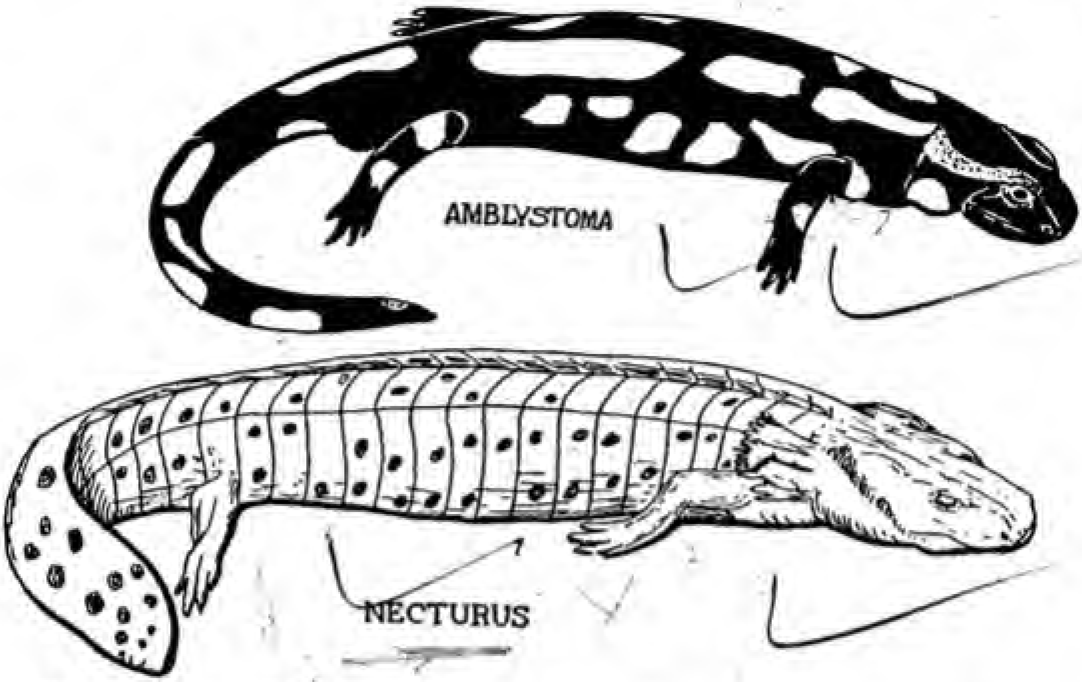


FIG. 318. Amphibia-Urodela. *Amblystoma tigrinum* the tiger-spotted salamander of North America. The eggs are deposited in ponds. The tadpoles, known as *axolotl*, often fail to complete metamorphosis but start reproducing. *Necturus*, the mud-puppy, has perennial gills.

FIG. 319. Amphibia-Salientia. *Bufo melanostictus*, the common Indian toad.

the adult is called ***neoteny***. The larva of *Amblystoma tigrinum* was formerly supposed to be distinct species of animal and named *Axolotl*, but its true nature was discovered when the axolotl underwent metamorphosis and became the well known *Amblystoma tigrinum*. The thyreoid gland is believed to be responsible for controlling the metamorpohsis in these animals. The axolotl can be experimentally induced to undergo metamorphosis.

FIG. 320. *Hyla* the tree frog has adhesive discs on the tips of fingers and toes as adaptation for climbing trees.

The amphibia are almost without exception beneficial, because they destroy large numbers of noxious insects. Some like the frogs are also useful as human food or as fish-baits.

RESUMÉ

1. The Amphibia represent the transition between the aquatic and terrestrial vertebrates.

2. Although they can live both on land and in water, the amphibians are not completely emancipated from the latter medium. They have to return to it for breeding.

3. The heart is three-chambered and in the single ventricle the arterial and venous streams are mixed.

4 Respiration is by gills, skin and lungs.

5. The Amphibia descended from ancient Crossoptrygian fishes.

6. The Amphibia are subdivided into the orders Anura, Urodela and Apoda.

7. Amblystoma often gives rise to perennial neotenic larvae called Axolotl that retain gills but reach sexual maturity and breed. Under suitable conditions metamorphosis is completed.

CHAPTER XX

REPTILIA

Reptilia.— The REPTILES are the first Vertebrates which became adapted or a completely terrestrial life. An amphibian is nothing more than a *glorified fish* with two pairs of limbs instead of fins. It may exist for a time on land, but it cannot stray far away from water to which it has to return for breeding. The reptile on the contrary is completely emancipated from water and can lay egg on the land The embryo is protected against drying by a series of membranes and floats in a liquid inside these membranes. One of these membranes functions as an embryonic lung. Though gill slits appear in the embryo, gills never develop and the adult respires wholly by the lungs. An outer porous shell ensures further protection while permitting the passage of air. The scaly covering of the adult aids in preventing loss of moisture from the skin.

Characters. —

1. Body covered by dry (*not slimy*) horny skin, with scales.
2. Single occipital condyle.
3. True sternum present.
4. Ribs attached to sternum.
5. Two pairs of limbs typically with 5 toes ending in horny claws (modified as paddles in aquatic reptiles and lost in snakes).
6. Heart imperfectly four-chambered (completely four-chambered in crocodiles). No conus arteriosus. Aortic arch one pair. Blood with nucleated erythrocytes.
7. Respiration always by lungs, functional gills never present.
8. ~~Cranial nerves twelve pairs.~~
9. Fertilization of ovum internal and eggs with much yolk.
10. The embryo is protected by a series of embryonal envelopes *amnion*, *yolk-sac chorion* and *allantois*.
11. Young hatch in an advanced state and resemble the adult. No metamorphosis.

Advances over Amphibia.—The reptiles show many advances over amphibians First is their ability to lay eggs on dry land. Among others may be listed 1 the completely ossified skeleton, 2 the better developed nervous system and sense organs, 3. improved respiration by the better developed lungs, 4. the mixing of venous and arterial blood being much less than in amphibia owing to the nearly complete separation of the ventricle into a right and a left half, 5 internal fertilization eliminates uncertainties of the sperm finding the ovum and 6. the hatching of the young in an advanced stage minimizes mortality.

Structure.—The main structural features of the reptiles are as below :

The auricles are two as in the frog but the ventricle is also divided into two by an incomplete septum. The heart of the crocodile has the ventricle completely divided. The venous blood that returns to the right auricle passes into the right ventricle and from there to

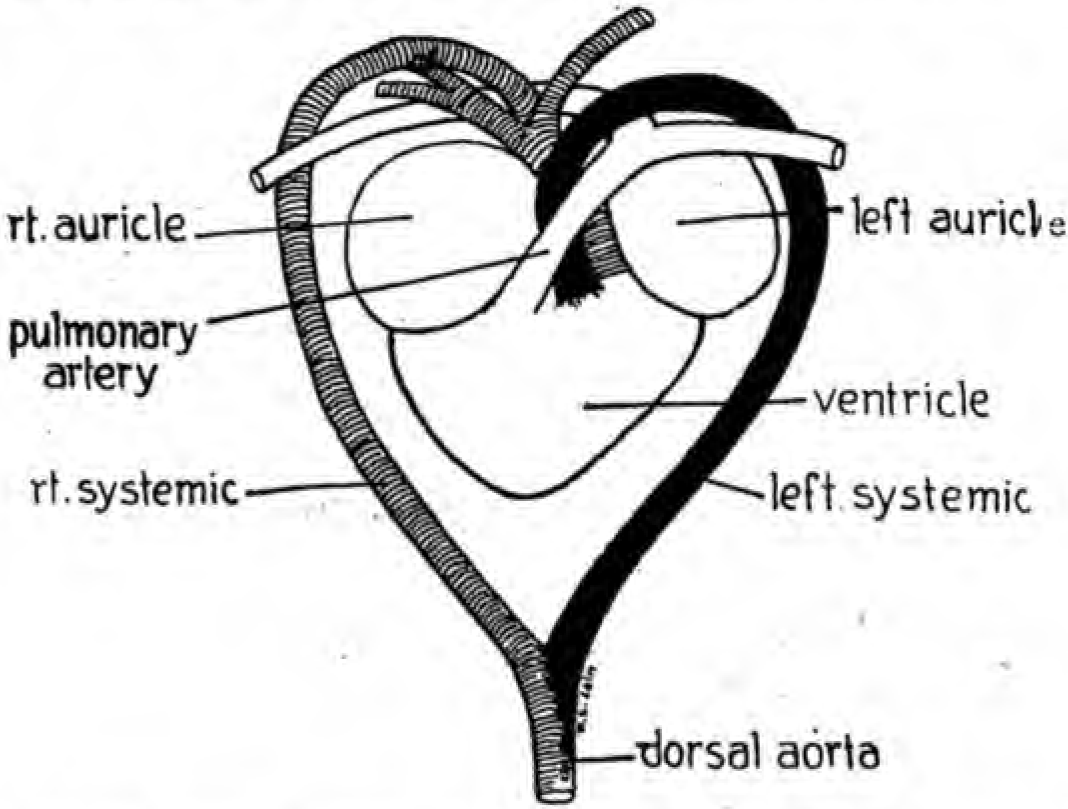


FIG. 321. Heart and associated blood vessels of a reptile. The ventricle is incompletely four-chambered. The right systemic arch arises from the left ventricle. From the right ventricle arises the pulmonary artery conveying the venous blood to the lungs. There is also a left systemic arch arising from the right ventricle and joining with the right arch to form the dorsal aorta, in which the venous and fresh streams mix. The carotid arise from the right arch and convey fresh blood to the head.

the lungs. The oxygenated blood returns from the lungs to the left auricle, thence to the left ventricle. From the ventricle it flows through the aortic arches to the dorsal aorta. The venous and oxygenated bloods mix to some extent in the incompletely separated ventricle but less so than in the frog. In the crocodile both the left aortic arch and the pulmonary artery arise from the right ventricle, so that here also there is some mixing of the two streams. Both renal portal and hepatic portal systems are present. The bronchi are highly branched and the alveoli of the lungs are more numerous than in the amphibians.

The brain has a ***cerebral cortex***, not found in the frog. The cerebral cortex serves as a higher association and co-ordination centre.

Classification.—The Reptilia are divided into six subclasses: 1 Anapsida, 2. Ichthyopterygia, 3. Synaptosauria, 4. Lepidosauria, 5. Archosauria and 6. Synapsida.

Subclass I. ANAPSIDA

Order 1. COTYLOSAURIA. Stem reptiles. Extinct. Example: *Diadectes*.

Order 2. CHELONIA. Body broad, enclosed in "shell" of dorsal carapace and ventral plastron. Thoracic vertebrae and ribs fused to shell. No teeth; jaws horny, marine or fresh-water. Examples: Tortoises, turtles.

Subclass II. ICHTHYOPTERYGIA

Order 3. ICHTHYOSAURIA. Marine fish-like, extinct *Ichthyosaurus*.

Subclass III. SYNAPTOSAURIA

Order 4. SAUROPTERYGIA. Marine, extinct *Plesiosaurus*.

Subclass IV. LEPIDOSAURIA

Order 5. RHYNCHOCEPHALIA. Lizard-like; with abdominal ribs. Example: *Sphenodon* tuatara.

Order 6. SQUAMATA. Horny epidermal scales. Vertebrae procoelous. Quadrate movable. Anus transverse.

Suborder i. L a c e r t i l i a (=Sauria). With four limbs, rarely reduced or absent (Fig. 323), Mandibles fused in front. Tongue not forked. Examples: Lizards, chameleon (Fig. 322) *Varanus* monitor *Heloderma* Gila monster (Fig. 325) *Anguis* slow worm—"limbless" lizard (Fig. 325).

Suborder ii. S e r p e n t e s (= Ophidia). No limbs, tympanum, sternum or urinary bladder. Mandibles joined by ligament in front. Right lung reduced. Tongue forked and protrusible. Examples: Snakes.

Subclass V. ARCHOSAURIA

Order 7. CROCODILIA. Powerful jaws with conical teeth. Four limbs with clawed toes. Tail long and compressed. Thick and leathery skin with horny scutes. Heart 4-chambered. No bladder. Examples: Alligators, Crocodiles, *Gavialis*.

Order 8. PTEROSAURIA. Extinct flying *Rhamphorhynchus* (Fig. 335) and *Pteronodon* (Fig. 336).

Order 9. SAURISCHIA. Extinct dinosaurs. Examples: *Brontosaurus*, (Fig. 331) *Diplodocus*, *Stegosaurus* (Fig. 333) *Triceratops* (Fig. 334) and *Iguanodon* (Fig. 332).

Subclass VI. SYNAPSIDA

Order 10. PELYCOSAURIA. Extinct carnivorous forms from which the mammals descended. Examples: *Dimetrodon* (Fig. 330), *Cynognathus*.

SOME LIVING REPTILES

Chelonia.—The tortoises and turtles are protected by a hard shell consisting of a dorsal ***carapace*** and a ventral ***plastron***. When threatened with danger, the head, neck, legs, and tail can be drawn into this shell. The shell is made up of several plate-like bones closely sutured to one another and often covered by definite patterns of horny scutes on the outer surface. The thoracic vertebrae and the ribs are generally

fused with the carapace. The jaws lack teeth but have horny sheaths for crushing the food.

Chelonians live both on land and in the sea. Respiration is by lungs and since the shell prevents expansion and contraction of the lungs, the air is pumped into them by the movements of the neck and legs. Some aquatic turtles have thin-walled sacs in the cloaca to serve as a kind

FIG 322. Order Chelonia : turtle. Order Squamata : Chameleon.

of gills. They can remain under water for a considerable period. Eggs are deposited in nests in the ground. Turtles and tortoises abound in America. Some of them are large and weigh nearly 400 lbs.; the largest turtle weighs 1000 lbs. They attain an age of nearly four hundred years.

Squamata.--The squamata include the chameleons, lizards and snakes. They are characterized by the scaly covering that is periodically shed.

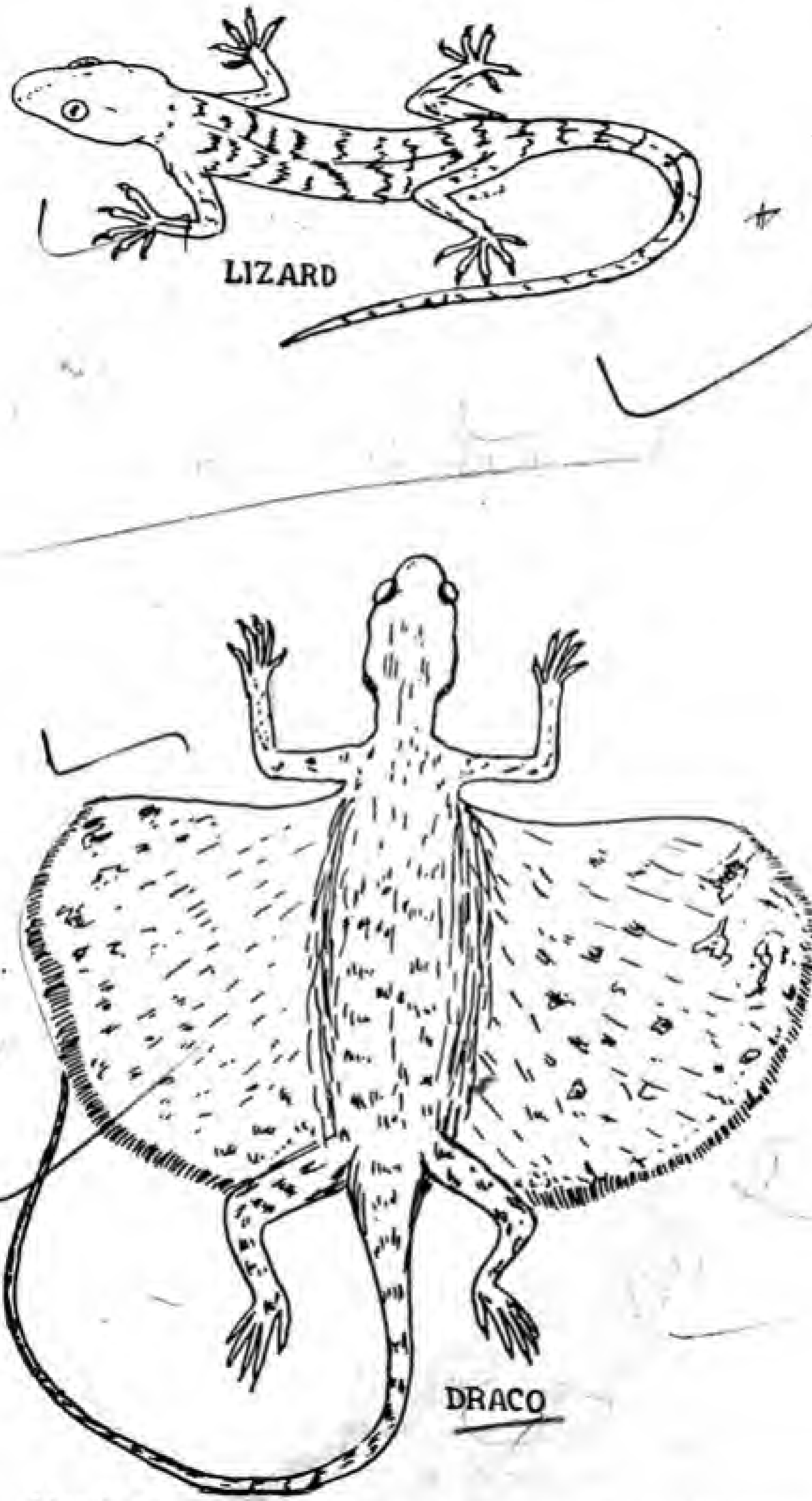


FIG. 323. Lizards inhabit warm regions and have toes adapted for running over smooth surfaces. The draco or " flying dragon " occurs in south eastern Asia and East Indies. The ribs extend beyond the sides of the body and are covered by a thin membranous fold of skin that acts as a plate.

In the lizards the scales peal off in pieces but in the snakes the entire scaly covering comes off at one time.

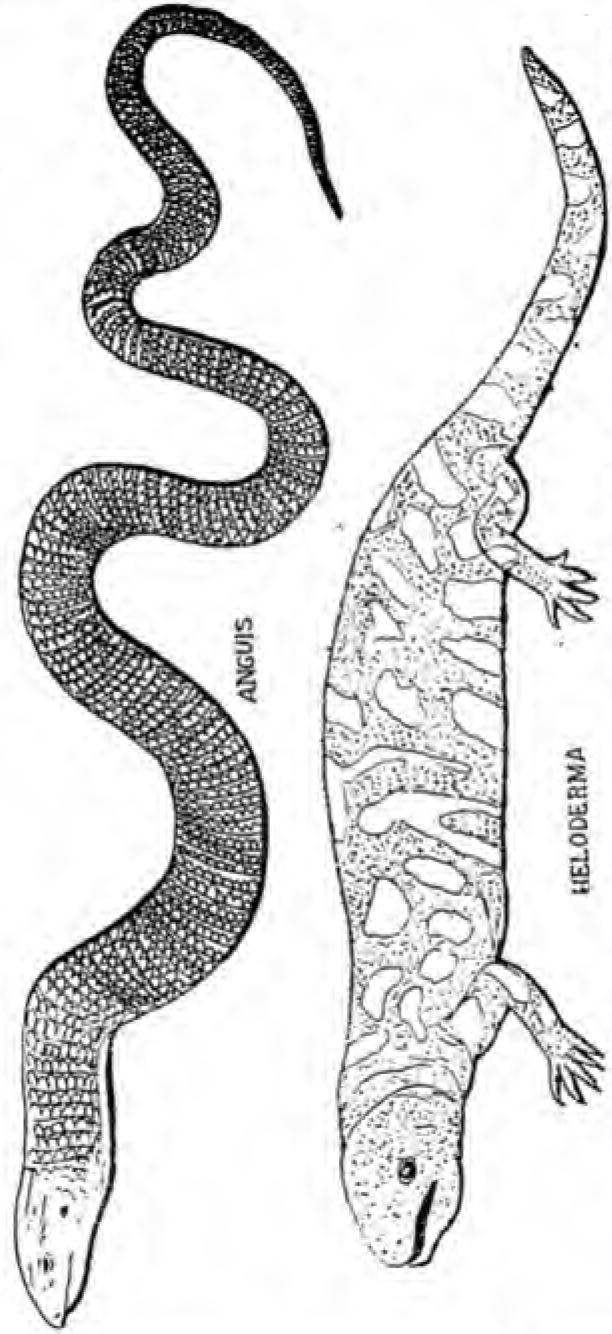


FIG. 324. Reptilia-squamata: *Anguis fragilis*, the "slow worm" or "blind worm" occurs in Europe, Western Asia and Northern Africa. *Heloderma suspectum*, the gila monster, is the only poisonous lizard. It occurs in Arizona and Mexico

Chameleons are arboreal forms with a long prehensile tail that is used for coiling round branches. It cannot easily break off and if broken is not regenerated. The tongue is peculiar: it is club-shaped (Fig. 322) and is provided with a sticky secretion. It can be shot out to about half a foot to capture insects for food. Chameleons are well known for changing colour.

Lizards.—The lizards are recognized by the presence of four limbs adapted for running, climbing or digging. They can break off their tail if danger threatens and a new tail regenerates. Some lizards are limbless and superficially resemble snakes. Legless lizards are distinguished from snakes by the presence of movable eyelids, external ear opening and overlapping scales on the ventral surface instead of the transverse scales of the snakes. The tongue cannot also be retracted into a basal sac. A urinary bladder is present but the excretory products are semi-solid white "urates" passed on with the faeces as in birds. Geckos are the common lizards. The only poisonous lizard is *Heloderma* (Fig. 324), the gila-monster of America. Its poison is as virulent as that of the dreaded rattle-snake but the mechanism for injecting the poison is poorly developed. Monitors or *Varanus* are large lizards that often attain a length of 12 feet.

The legless lizards inculde *Ophiosaurus*, the so-called "glass-snake" from Europe and America; *Anguis* the "slow-worm" or "blind-worm" from Europe, Africa and Asia; Amphisbaenids "worm lizards" from America; *Pygopus* the snake-like lizard from Australia; *Anniella* the silvery footless lizard from California and *Typhlops* the "worm snakes" of the old and new worlds. *Draco* (Fig. 323) or the flying lizard is common in the Oriental Region.

Snakes.—The snakes are among the most highly specialized of modern reptiles. Their striking character is the absence of limbs. Some have vestiges of the limbs. They are readily separated from the limbless lizards by 1. the absence of eyelids, 2. presence of an elastic ligament between the two halves of the lower jaw, 3. absence of external ear and 4. the scales on the ventral surface of the body not overlapping but forming broad transverse rows. The bones of the skull are loosely joined and several of them can move one upon another. Teeth are pointed backward and are present on the jaws and bones on the roof of the skull. They are used to hold the food while being swallowed; snakes never bite or chew the food but swallow the prey alive. Poisonous snakes have a pair of specialized teeth, the "fangs" on the maxillary bones. Each poison fang is grooved and conducts the poison from the poison glands (Fig. 329). The tongue is peculiar: it is slender and forked at the tip. It can be protruded through a notch in the mandible even when the mouth is closed. The tongue aids in smelling. The ligament in the lower jaw and the loose articulation of the skull bones enable the mouth to be opened very wide and the snakes can thus swallow prey much thicker than themselves. There is no sternum and the ribs are

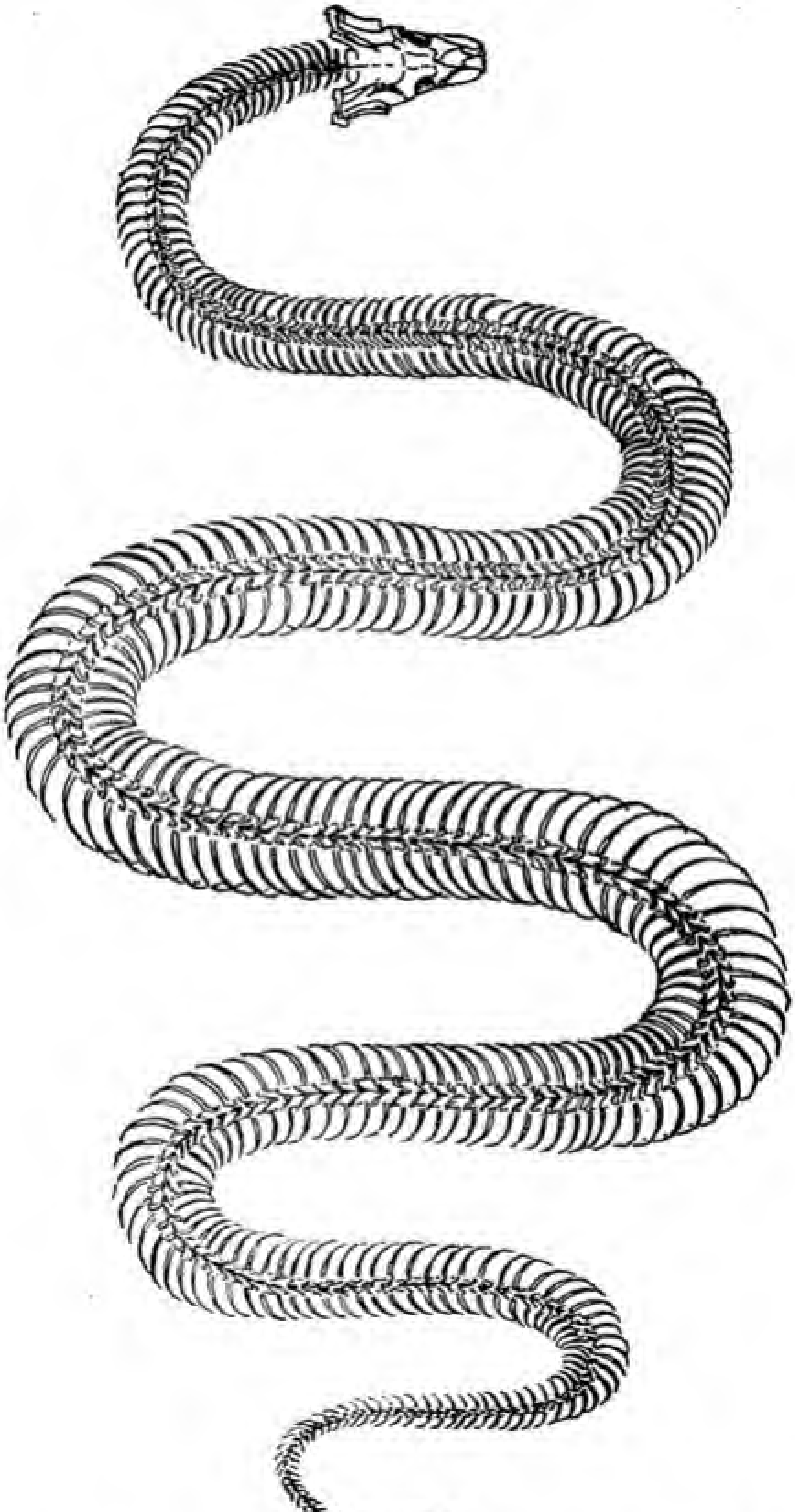


FIG. 325. Skeleton of snake. Note the absence of girdles, limbs and sternum.

Viper russeli (Fig. 329) is the common species, about 5 feet long, brown or light brown. The sublingual scales are in contact with the fourth or fifth infralabial, subcaudal scales divided and there are three series of large spots on the back.

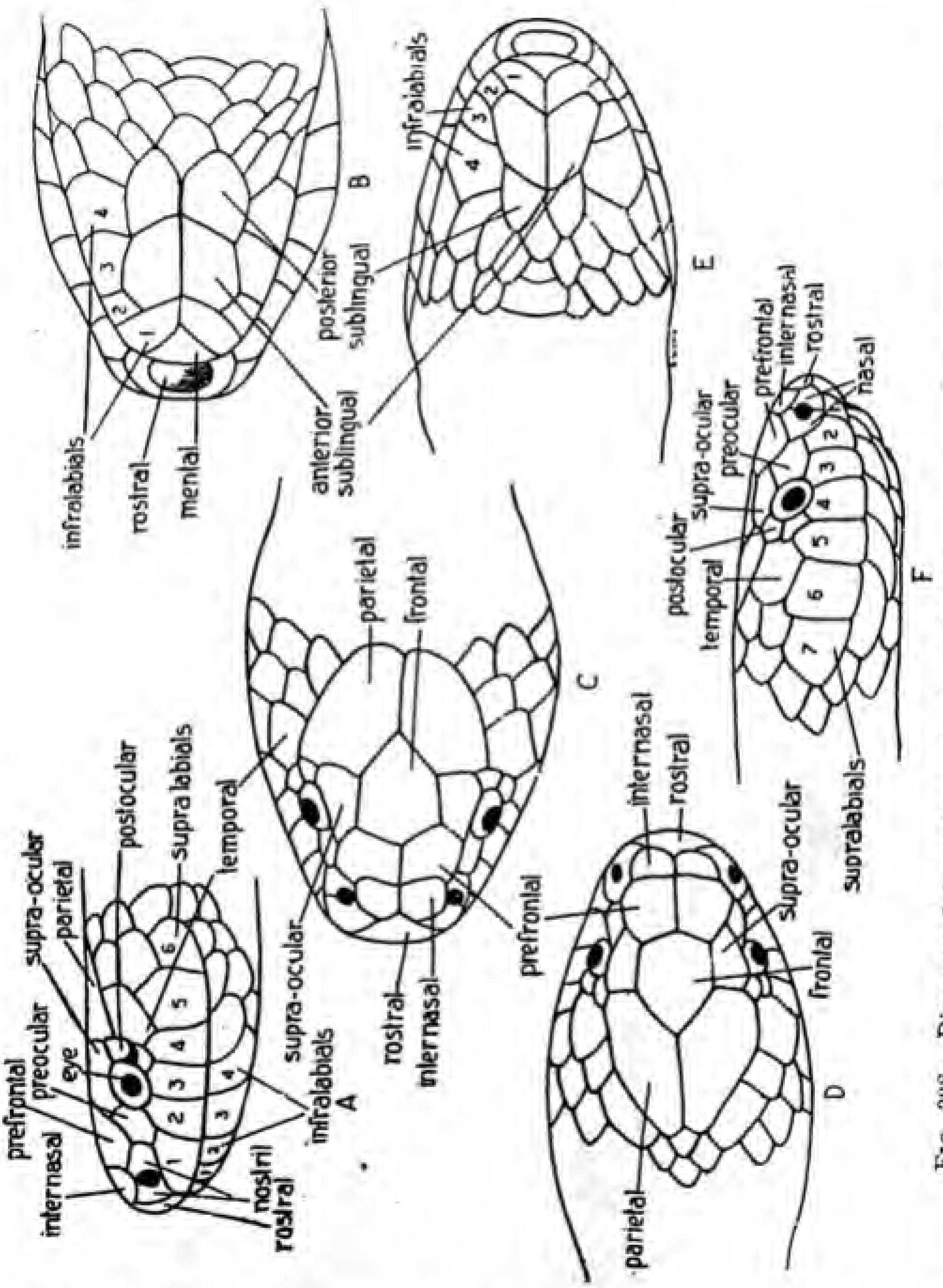


Fig. 328. Diagram of the scales on the head of kraits. A. Lateral, B. Ventral and C. Dorsal views of *Bungarus fasciatus*, D. Dorsal, E. Ventral and F. Lateral views of *Bungarus coeruleus*.

The deadliest of all land snakes is the rattle-snake *Crotalus* from America. It possesses a series of hollow epidermal buttons linked together to form a rattle (Fig. 329) at the tip of the tail. A rattling noise, often

audible twenty yards away, is produced by the rapid vibration of the tail as a warning of the approach of the rattle-snake.

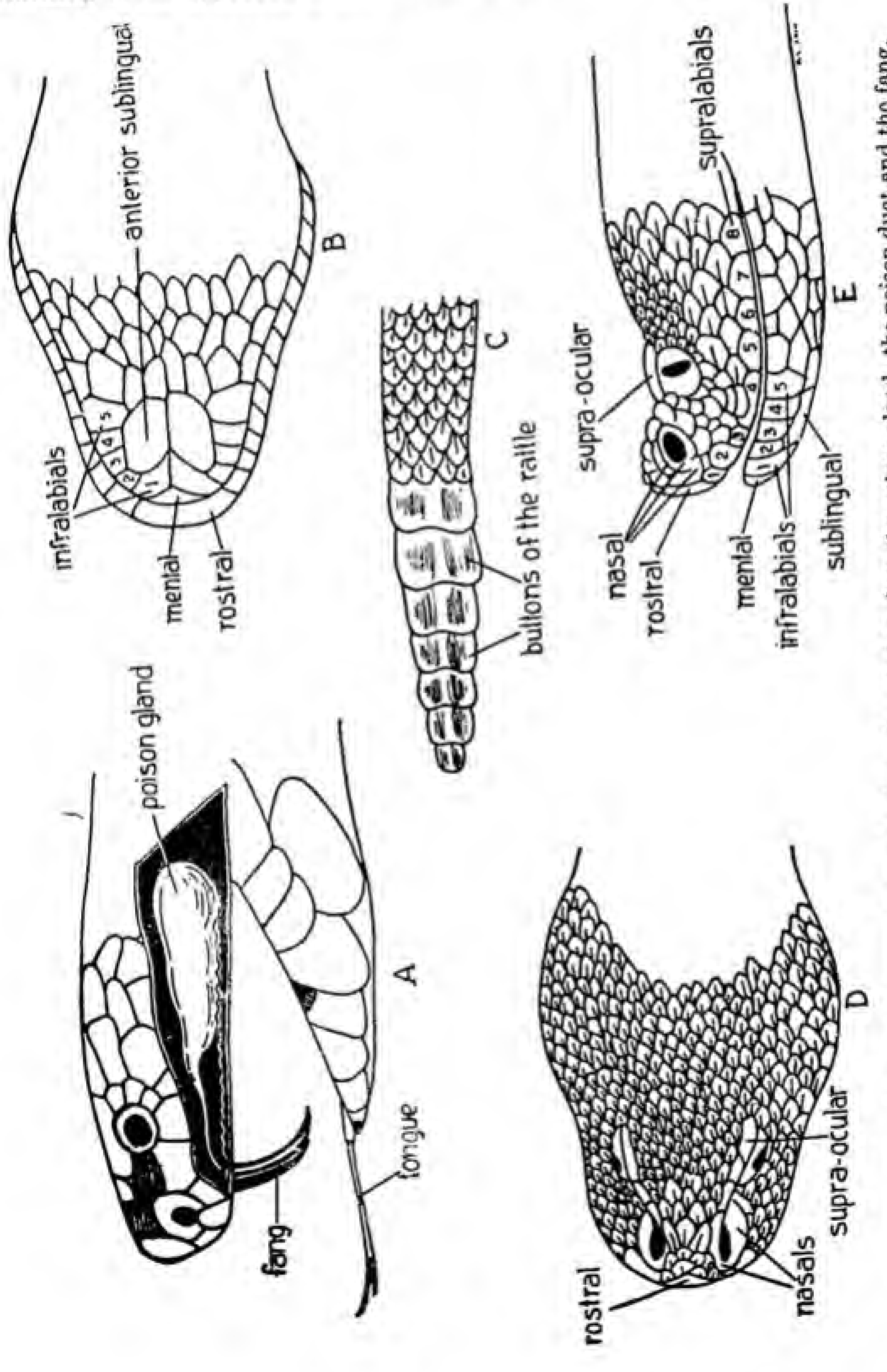


FIG. 320. A. Head of cobra in lateral view, dissected to show the poison gland, the poison duct and the fang. B. Ventral, D. Dorsal and E. Lateral views of the head of *Vipera russelli* showing the arrangement of scales. C. Tail of the rattle snake.

It is not always easy to distinguish a venomous from a non-venomous snake. The difficulty is increased by the fact that often harmless snakes have a surprising superficial resemblance to certain highly venomous species. Some species of the harmless *Lycodon* thus resemble the kraits. Other harmless snakes may similarly be confused with the cobra. The only reliable character is the presence of grooved teeth.

Snake-bite and snake-poisoning.—Venomous snakes may bite but often may not cause snake-poisoning either because the venom is not injected or is in insufficient dose to lead to serious symptoms. In most cases fright itself gives rise to series of symptoms and even ends fatally, without the person having been poisoned by the snake at all.

Fresh snake venom is a yellow, odourless and tasteless liquid. It contains two types of harmful substances : one that destroys nerve cells and blood vessels and the other digests living substances. According to the effect of their venoms on the victim two distinct kinds of snakes are generally recognized : 1. *Colubrine* and 2. *Viperine*. The Colubrine snakes include the cobra, the hamadryad, the krait and coral snakes. The viperine snakes include all vipers. The colubrine venom affects the central nerves and causes death by paralysis of the respiratory centres in the brain. The viperine venom does not affect the nervous system as a whole but only the vasomotor centre. The heart and the blood are also affected. Death results from paralysis of vasomotor centre, blood poisoning and bleeding.

THE SYMPTOMS OF COBRA-POISONING ARE :

1. The victim becomes gradually weak
2. Gradual paralysis sets in the legs and the victim sits or lies down.
3. The paralysis mounts gradually upwards to the trunk and head.
4. Eyelids droop.
5. Swallowing becomes difficult.
6. Lower lip falls down and saliva dribbles from the open mouth
7. Respiration gradually depressed.
8. Heart and consciousness not affected.
9. Death by respiratory failure.

VIPER POISONING LEADS TO :

1. Reduction of blood pressure due to paralysis of vasomotor centre.
2. Heart weakness.
3. Blood often clots in blood vessels if venom is in large dose.
4. Bleeding is profuse and persistent if the dose is not very large.
5. The red corpuscles are destroyed.
6. Death by loss of blood, toxemia and heart failure.

Efforts to cure victims of snake-bite have led to numerous irrational, fanciful and utterly useless practices. The so-called "cures" are not only worthless but often harmful and victims have been known to die of the "cure" before the venom could finish them! The only sure and safe treatment is injecting ***antivenines.*** In 1887 Sewell discovered that repeated injections of minute sublethal doses of snake venoms into pigeons gave rise to the appearance of an ***antibody*** in the blood of the pigeon. The bird thus became actually ***immune*** to a subsequent snake bite. In practice, horses are immunized in this way to the venoms of different snakes. The blood serum of the immune horse is the ***antivenine,*** which if injected into a snake-bite victim destroys the venom

Snake venom is used by savage men for poisoning arrow tips. The venom is also used in modern medicine as a cure for various diseases, for example, cobra venom relieves severe pain in inoperable cancer.

Crocodilia.—The Crocodilia include some of the largest of the living reptiles. They comprise the lizard-like crocodiles, alligators, gavials and caimans. They are wholly carnivorous and inhabit almost exclusively fresh-water lakes and rivers in tropical and subtropical regions. Some have taken to the sea near the shore. Though they are very good swimmers, they spend a good deal of their time on the shore. They generally breed on land.

The body is large, with large head, powerful jaws bordered by numerous bluntly conical teeth. The four limbs are short and end in clawed toes with webs between: five toes in front and four behind. The tail is compressed, long and heavy. Skin is leathery and is provided with horny scutes, often reinforced by dermal bones beneath. The ear opening is small and is protected by a flap of skin. The external nostrils are at the tip of the snout. The eyes bulge on the surface of the head above. The animal can lie just under the surface of water with only the eyes and nostrils exposed. The eyes are covered with lids. The nostrils and the ear openings can be closed by valves when the animal dives under water.

The tongue is flat and cannot be thrust out but it can be lowered and pushed back to close the oesophagus. This prevents the water from entering the oesophagus when the animal opens the mouth under water. There is a bony palate that separates the nasal chamber from the buccal cavity as in ourselves. The internal nares open far backwards into the pharynx. The lungs and heart are located in a thoracic cavity separated by a ***diaphragm*** from the abdominal cavity as in mammals. The heart is also four-chambered ; two auricles and two ventricles.

The living Crocodilia are divided into three groups: 1. Crocodiles and alligators, 2. Borneo gavials and 3. gavials of India. Crocodiles and alligators have broad and flat head, with few large teeth and incompletely webbed toes. The Bornean gavials have a moderately slender snout and better webbed toes than in crocodiles; the hind toes are completely webbed. The Indian gavials are restricted to the rivers of India. The Ganges gavial has very long and slender snout, with numerous small, slender teeth and fully webbed toes. This is more completely aquatic than crocodiles or alligators and feeds almost exclusively on fish.

Crocodiles lay eggs in holes in sand or under stones or leaves. The female stands guard over her eggs.

Skin of crocodiles and alligators are manufactured into fancy leather. Their eggs and flesh are eaten in some countries. In Africa and India crocodiles cause a number of human deaths. In some parts of South America they are very destructive to cattle.

EXTINCT REPTILES

The reptiles occupy a very minor place among animals at the present time, but in the great past they were the dominant Vertebrates. They were the adventurous pioneers who invaded the land surface of the earth in the great dim past and made it inhabitable for future men. They even invaded the air before there was any bat or bird. The story of the rise and fall of the mighty Reptilian empire on the earth is as interesting and perhaps even more sad than that of the Chaldeans, Chinese, Romans and Egyptians. The Reptilian history covers an unimaginably enormous stretch of time, which can only be written with nine figures—300,000,000 years! This is nearly a tenth of the age of the good old earth itself! Springing from fish-like Amphibians over 300 million years ago in the Palaeozoic Era (*Vide* Chapter XXV), they became dominant during the long Mesozoic Era, appropriately called the 'Age of Reptiles', and are now in decay. Group after group, legions after legions, of small, large or gigantic, elegant or frightful, spectacular or bizarre reptiles appear in succession during the Mesozoic Era, only to become ***extinct*** in their turn. A colossal calamity, of a magnitude simply unknown anywhere else, appears to have overtaken the mighty and ancient empire towards the close of this Era.

A Great Ancestor of Man.—One of the oldest and truly the oddest-looking of all extinct reptiles is *Dimetrodon* (Fig 330). It belonged to the Synapsida which were destined later on to give rise to the mammals

including man. It existed nearly 220 million years ago. *Dimetrodon* was an aggressive carnivore. It was larger than a full-grown man and measured fully 11 feet long and not less than 7 feet high.

It has rather an unusual feature, because of the presence of the greatly elongated bony neural spines rising upwards from the backbone and connected by skin, giving the truly fantastic appearance of a fully rigged ship.

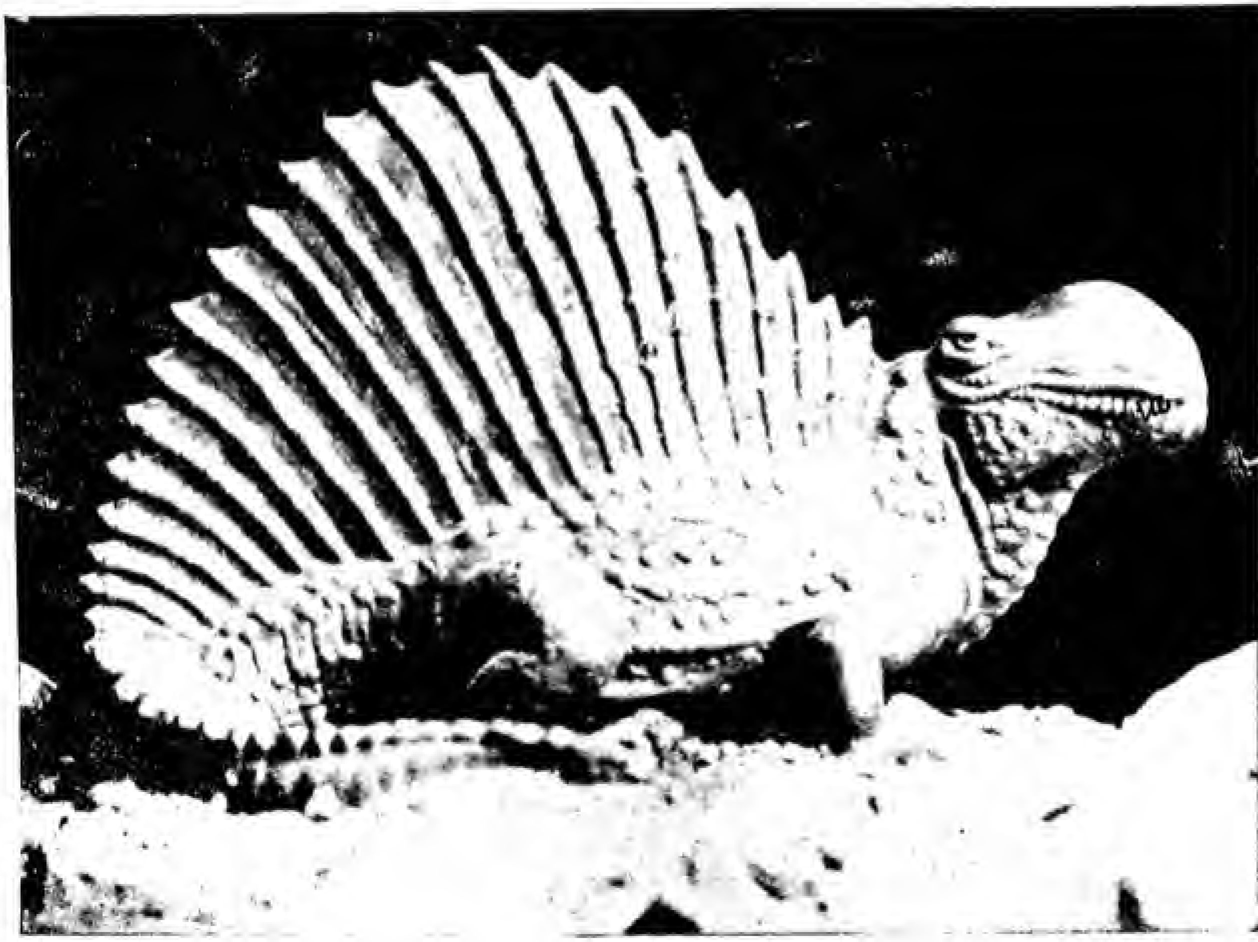


FIG 330. A great ancestor of man. *Dimetrodon* or the spined pelycosaurian monster, an agressive carnivore, 11 ft. long and over 7 ft. high. Date 220 Million years ago. (*Author's original photo of a reconstruction in the Zoology Museum, St. John's College, Agra*). (*Reproduced by the kind permission of the Editor, St. John's College Magazine*).

Dimetrodon ruled over a land devoid of beauty as we know it; without gay flowers and fruits, a silent world without singing birds and chattering monkeys. A vast glacial climate gripped what are now South America, Australia, South Africa and India, which lay under hundreds of feet of ice. His subjects were mostly cockroaches, enormous and

;-looking cockroaches, stout scorpions of a sort, clumsily built
:s and giant ungainly and hesitating dragonflies over two feet
He levied a heavy toll on them.

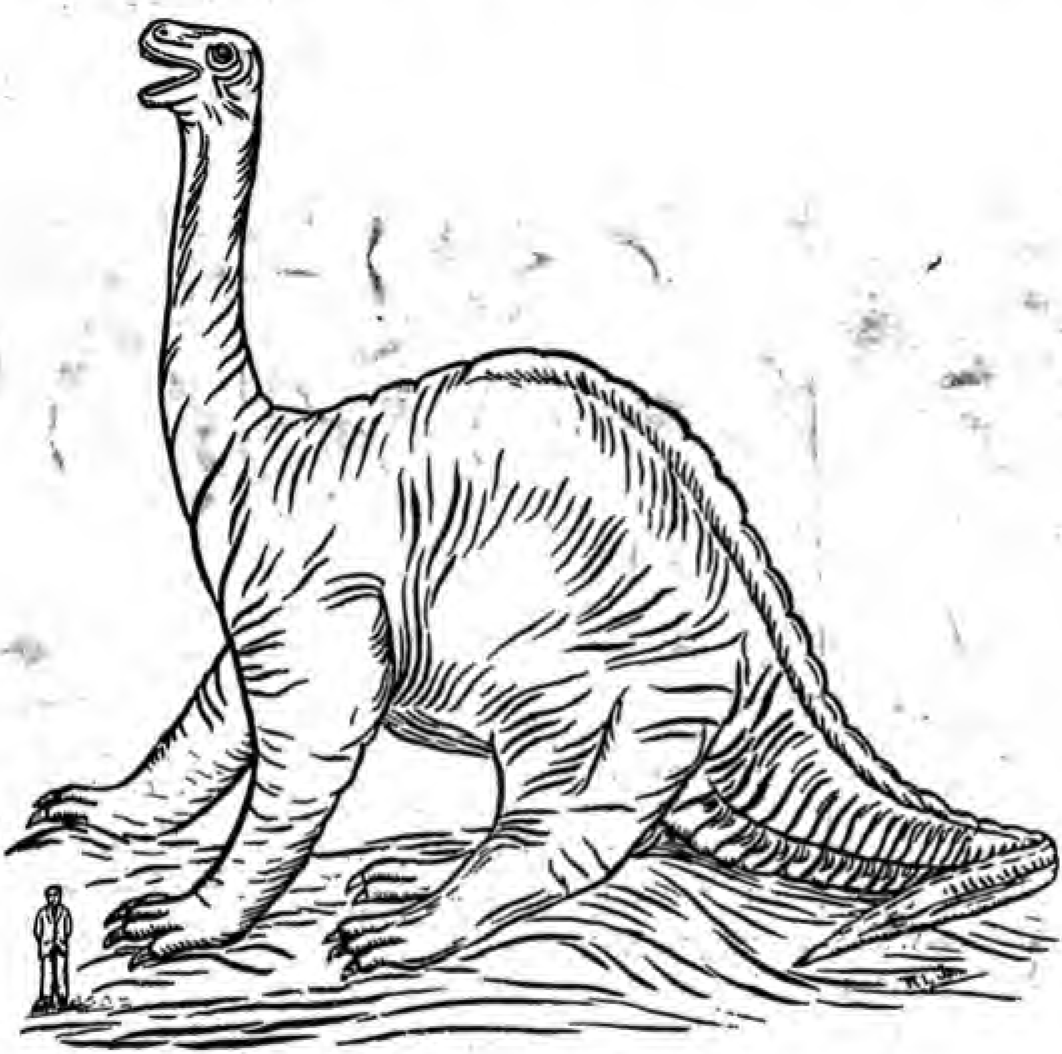


FIG. 331. *Brontosaurus.*

Dinosaurian Dynasty.—Perhaps the most spectacular monsters of all times were the dinosaurs, which were immortalized in the 'Lost World' by the immortal creator of Sherlock Holmes. They arose about 185 million years ago from an older stock, namely the Thecodont Reptiles and soon became the dominant land animals. Among the dinosaurs we meet with the largest of all land animals of all times. Some of them were very large, over 87 feet long and tipped the scale at 50 tons! Others were no longer than a common pariah dog. Certain of the dinosaurs were

carnivorous the but rest became pious converts to vegetarianism. The early herbivorous dinosaurs stood or jumped on their hind legs, but later on, protesting against such new-fangled most unreptilian bipedal fashions, several of them reverted to the respectable old four-footed gait of their fore-fathers.

FIG. 332. *Iguanodon*, the first of the great dinosaurs to be discovered, stood 15' high on its hind legs. It became extinct about 120 million years ago. (*Original photograph of a reconstruction in the Zoology Museum, St. John's College, Agra*).

Iguanodon (Fig. 332), the first of the great dinosaurs to be discovered, stood nearly 15 feet high on its hind legs, very much like a giant kangaroo. While running, which was its normal mode of locomotion, it touched the ground only now and then with its fore feet. It was a herbivorous dinosaur, with powerful tail and hindlegs. The fore feet were provided with five fingers, of which the thumb had an enormous claw, at least one foot long! The hind feet, which had only three toes, were very much like those of a bird, which are in fact believed to have descended from an ancestor not very much unlike the Iguanodon. The tail served as a balancer and emergency stool along with the hind legs. Complete skeletons, nearly 80 feet long, of twenty-nine Iguanodons were discovered in a coal mining village near Brussels; a mass grave of a herd of Iguanodons, which had probably been carried by a current into an ancient whirlpool. Iguanodons flourished during the Upper Jurassic and Lower Cretaceous epochs, estimated over 120 million years ago.

Monsters with Duplicate Brains.—Another herbivorous dinosaurian monster, which was a contemporary of *Iguanodon*, is the sauropod reptile, *Brontosaurus* (Fig. 331) meaning 'thunder reptile' with reference to the noise it is supposed to have made while walking, the fossil remains of which were discovererd in the Upper Jurassic rocks of Wyoming and Colorado in North America. Unlike *Iguanodon*, *Brontosaurus*

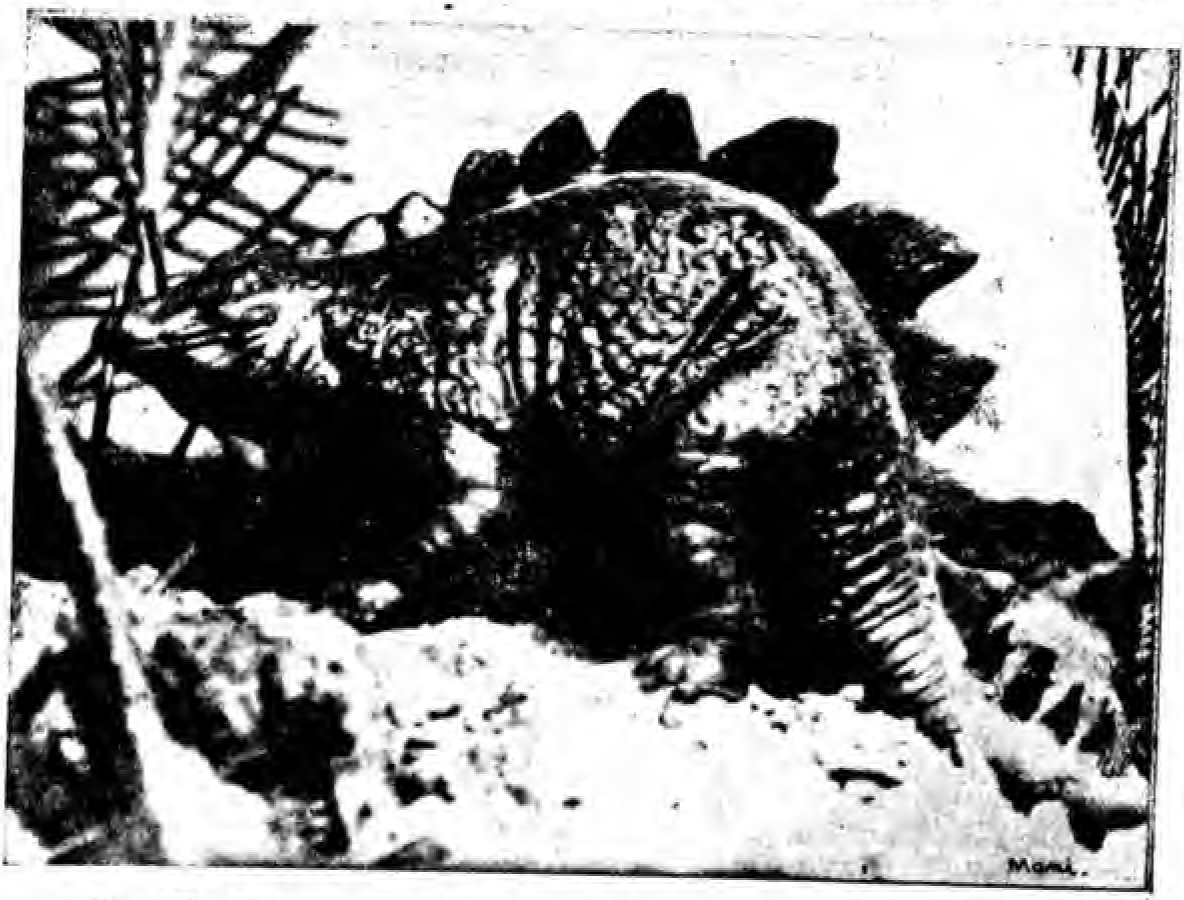


FIG. 333 *Stegosaurus*, a giant crested dinosaur, measured 18-30 ft. long and was taller than an elephant. Double series of large wedge-shaped dermal armour plates on the back, nearly a yard high, give it a bizarre appearance. (*Original photograph of a reconstruction in the Zoology Museum, St. John's College, Agra*).

did not believe in standing on two legs; it was a respectable quadruped, with five hoofed digits on each limb. Its size was about 60 feet. It had a long slender neck, at the end of which was a ludicurously small head, enclosing a minute apology for a brain. It has been very often suggested that it must have been a denizen of the coastal marshes and that it probably fed on the luxuriant water plants, walking comfortably on the bottom of the lakes, with only its head out of water.

A remarkable feature of this giant was the fact that it had a second 'brain' in the hip region in the shape of an enormous swelling of the

spinal cord, as if to compensate for the shamefully minute size of the brain in the head. Despite its double brain it must have been an extraordinarily stupid creature for its size. It was an easy prey to carnivorous reptiles.

Armoured Giants.—The slow moving herbivorous quadrupeds were thus at the mercy of the carnivorous and nimble-footed Ornithischian reptiles. They were therefore in need of some sort of armoured protection against their enemies; thus came the armoured dinosaurs.

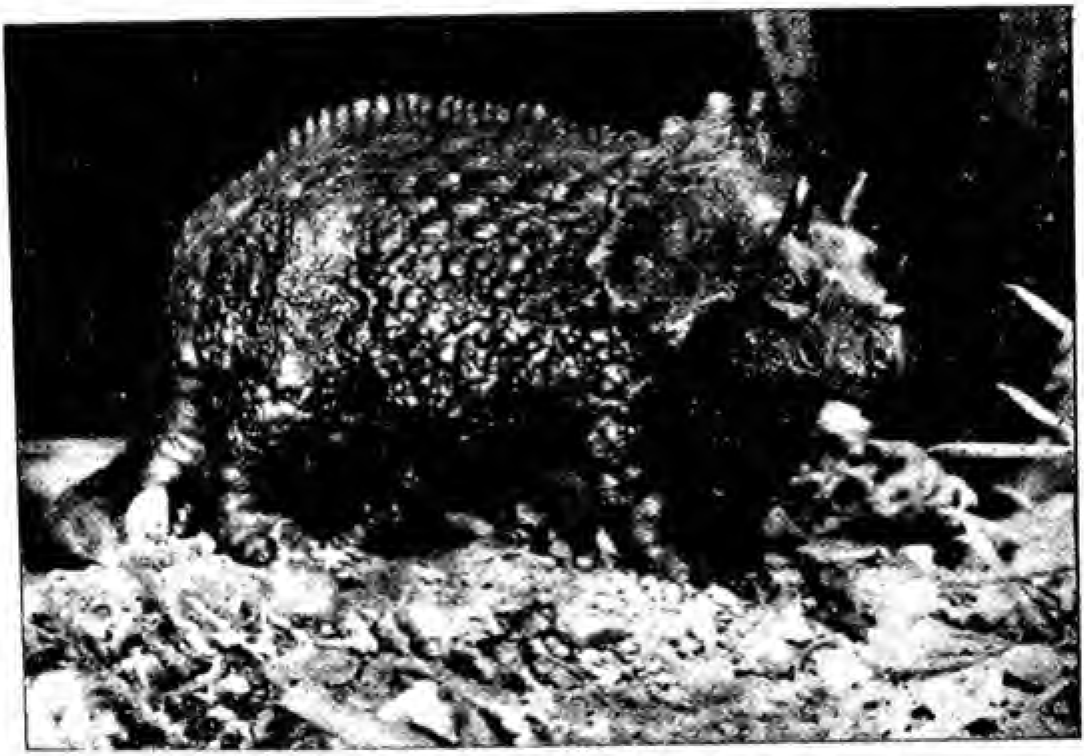


FIG. 334. A frilled monster, *Triceratoceps* or the three-horned armoured herbivorous dinosaur, as tall as an elephant and nearly 25 ft long. Date over 80 million years. (*Author's original photo of a reconstruction in the Zoolozy Museum, St. John's College, Agra*) (*Reproduced by kind permission of the Editor, St. John's College Magazine*).

From the Upper Cretaceous rock of Wyoming are known complete skeletons of the three-horned, gigantic, herbivorous, predentate dinosaur called *Triceratoceps*. The body of this monster was 25 feet long and as large as that of an elephant. Its skull was 7 feet long, but was practically all bone, with just an atom of brain. The back part of the skull had a curious long bony frill, effectively covering the delicate short neck from above. It had a curious rhinoceros-like appearance and its head was armed with two horn-like processes in front and a single horn on the nose, all of which made it very formidable in attack. It had only

to veer round and the enemy was in danger of being impaled. The fore limbs were shorter than the hind ones; they had five hoofed digits. The skin was studed with hardened armour plates.

Another armoured extinct monster is the giant crested dinosaur, *Stegosaurus* (Fig. 333), which presents a truly bizarre and a most grotesque appearance. It was nearly as high as a full-sized bull elephant and measured 18 to 30 feet long but with a ridiculously small head. It was indeed all brawn and no brain : it has in fact the distinction of having possessed the smallest brain amongst the land vertebrates. Like *Brontosaurus* it also boasted an *ersatz* brain in the hip region.

The most remarkable feature, however, about *Stegosaurus* is its double series of large alternating triangular dermal armour plates and spines on the neck, back and tail, supported inside by flattened neural spines from the backbone. The largest of the armour plates, nearly a yard high, lay above the hips and decreased in size both in front and behind. Inspite of this formidable armoured protection on the back, *Stegosaurus* was easily crippled by a flank attack. It probably fed on succulent plants.

Reptilian Supremacy of the Air.—Springing from the primitive Thecodent reptiles in the beginning of the Mesozoic Era nearly 250 million years ago, the Pterosauria or the flying reptiles gradually spread their domain in the air, flourished for nearly 200 million years and became extinct in the Cretaceous epoch. Two groups of pterosaurians are known : the Rhamphorhynchoids and the Pterodactyloids. They appear to have been chiefly flesh-eaters and probably roosted on coastal rocks and swooped down on their wings to the surface of water to catch fish by their elongated beak or jaws, much as our modern sea birds do.

Rhamphorhynchus (Fig. 335) was a grotesque-looking giant flying lizard of the Jurassic epoch nearly as big as a man, with a long head and short body. The tail is rather long like that of a giant lizard. The fore limbs were enormously elongated, with the fourth finger very long to support an expansion of the skin in the form of a wing, which was attached behind to the thigh. As in the birds, its bones were pneumatic *i. e.*, hollow and filled with air to give lightness to the body. The sternum or the breast bone had similarly a strongly developed bony keel projecting downward and forward for the attachment of the great muscles which worked the wings. The eyes were very large. The neck was slender and elongated, no doubt to facilitate the capture and handling of fish. The teeth were long, sharp and pointed outwards and

forwards, which was rather an unusual feature in a fish-eating animal. The hind legs were poorly developed and without doubt the normal mode of locomotion was flight. It is difficult to understand how it got about when not in flight or how the "take-off" was effected from level ground. Some people believe that the animal shuffled clumsily about on all fours touching the ground with the three small fingers and the wings turned back. Because the hind legs were extremely poorly formed such a bipedal method of walking must have been impossible and probably the small toes were used in clutching and clinging to rocks. It must have rested hanging head downward much as bats do.

FIG. 335. *Rhamphorhynchus*, a grotesque-looking flying lizard as big as a man. Date 150 million years. (*Author's original photo of a reconstruction in the Zoology Museum, St. John's College, Agra*). (*Reproduced by the kind permission of the Editor, St. John's College Magazine*.)

The Pterodactyls flourished about 80 million years ago, during the Jurassic epoch, and became extinct about 60 million years ago in the Cretaceous Era. They varied in size from small forms no bigger than a common house sparrow to giants measuring about 30 ft. In the Upper Cretaceous rocks of Kansas have been discovered the giant *Pteronodon* (Fig. 336), taller than a man and with a wing span of nearly 27 feet. The skull is elongate and has developed a curious-looking crest, extending backwards as much as the beak projects forwards and looking very much like

the matted and tufted hair of an Indian sadhu. Like *Rhamphorhynchus*, *Pteronodon* had also many avian adaptations in its skeleton : the bones were pneumatic and a sternal crest was also present. It had a short tail and was undoubtedly better fitted for flight than *Rhamphorhynchus*. It could make forced landings and also take off practically from anywhere.

FIG 336. The hammer-headed flying moster *Pteronodon*, 27 ft. long and 13 ft. high. Date 80 million years (*Author's original photo of a reconstruction in the Zoology Museum, St. John's College, Agra*) (*Reproduced by kind premission of the Editor, St. John's College Magazine*).

The Fall of Reptiles.—It was the last of a glorious dynasty of flying reptiles and died out before the close of the Cretaceous epoch. The death of the *Pteronodon* was not only the end of the flying reptiles but also marked the finish, once and for ever, of the reptilian ascendancy. Their supremacy disappeared for good and the world lost some of the most gigantic and the most spectacular of all animals. Birds and Mammals slowly gained ascendancy.

What brought the wholesale disappearance of so many different kinds of such powerful and wonderful animals? No completely satisfactory explanation has yet been found for their extinction. Changes in the external conditions, especially as regards the distribution of dry land and water caused by the drifting of the continents, paucity of food, changes in vegetation, encroachment of natural enemies and diseases may have led to the extinction of certain monsters. They may have perished through civil warfare and rivalry among themselves. In many cases the race appears to die off from superannuation: the reproductive functions gradually decline in the race, much as in senescence of individuals and the race becomes extinct. One-sided or over-development in any direction, for example, excessive size, is injurious to the race and rapidly leads to extinction.

RESUMÉ

I. Reptilia

1. The Reptilia are the first vertebrates which became adapted for a completely terrestrial life. Their eggs, laid on land, are protected by a hard shell and embryonal membanes like amnion.

2. The circulatory system shows great advances over that of the amphibians. The heart is more or less completely four-chambered and respiration is entirely by lungs.

3. The Reptiles are grouped under Anaspida, Ichthyopterygia, Synaptosauria, Lepidosauria, Archosauria and Synaspida.

II. Living Reptiles

4. The living reptiles comprise the turtles, tortoises, lizards, snakes, alligators and crocodiles.

5. The snakes lack limbs, eyelids and external ear drum. The scales on the ventral surface form transverse rows of plates that aid in locomotion. The skull bones are movably articulated and permit of very large animals being swallowed.

6. Most snakes are nonpoisonous. The venomous snakes are mostly recognized by the ventral scales covering the belly completely. The common venomous species include all sea-snakes, cobras, kraits, coral snakes, vipers and rattle snakes.

7. According to the effect of their venom on the victim, snakes are classed as colubrine and viperine. The former include the cobras, kraits and coral snakes. Their venom paralyzes the respiratory centre of the brain. The viperine venom affects the heart and blood and the vasomotor centre. The only rational treatment for snake bite is to inject antivenine serum.

III. Extinct Reptiles

8. Reptiles formed the dominant vertebrates in the past but many have become extinct. The extinct forms include many spectacular, bizarre and gigantic species like *Dimetrodon*, *Brontosaurus*, *Stegosaurus* and *Pteronodon*.

CHAPTER XXI

AVES—BIRDS

Aves.—Birds are structurally very similar to reptiles: indeed they have been described as "glorified reptiles." Reptiles and birds are often put together in a single class *Saurapsida.* Feathers are almost the only distinctive feature of the class. All birds have feathers that clothe the body and insulate the heat. No other animals have feathers. The feathers are in reality modified scales. Unlike the ordinary reptiles, birds are "warm-blooded": the body temperature is independent and higher than that of the surrounding.

Fig. 337. Subclass Archaeornithes *Archaeopteryx lithographica*, the lizard-bird, the fossil remains of which were discovered in Solenhofen lithographic limestone in Bavaria (Germany). It was of the size of a crow, had a long lizard-like tail and the three fingers of the wing—modified fore limbs—had claws. The jaws bore teeth as in lizards. (*Drawn from a reconstruction in the Zoology Museum, St. John's College, Agra*).

Characters.—

1. Body covered by feathers.
2. The fore limbs are modified as wings. Modern birds lack claws.
3. The hind limbs are adapted for walking, running, perching or swimming. The tibia and toes alone are covered by scales.

4. Skeleton completely ossified and often hollow and filled with air.
5. Skull with one occipital condyle.
6. Mouth a projecting beak ; modern birds are toothless.
7. Sternum large and often with a large keel.
8. Pelvis fused to numerous vertebrae.
9. Tail reduced.
10. Heart fully four-chambered.
11. Only the *right* aortic arch is present.
12. Erythrocytes biconvex and with nucleus.
13. No urinary bladder.
14. Only the left ovary present.
15. Cranial nerves twelve pairs.
16. Fertilization internal.
17. Eggs rich in yolk and with embryonal membranes.

Classification.—

Class AVES. Birds.

Subclass I. ARCHAEORNITHES. Extinct bird with three fingers ending in claws, separate metacarpals, elongate tail and teeth in jaws. Example: *Archaeopteryx lithographica* (Fig. 337) from lithographic stone of Jurassic rocks of Germany.

Subclass II. NEORNITHES. Fused metacarpals.

Superorder i. ODONTOGNATHAE. Extinct giant toothed birds. Example: *Hesperornis*.

Superorder ii. PALAEOGNATHAE. Large, walking, flightless and toothless birds.

Order 1. Struthioniformes. Large flightless birds without the sternal keel ; with pubic symphysis which is not met with in other birds ; toes only two. Example : *Struthio camelus* the ostrich (Fig. 338) 7 feet tall, over 300 lbs. in weight, male incubates the eggs, inhabitant of arid deserts.

Order 2. Rheiformes. Flightless birds without sternal keel and 3 toes Example : *Rheas* of S. America.

Order 3. Casuariiformes. Flightless birds with unkeeled sternum and 3 toes. Examples : *Dromaeus* the emu and *Casuarius* the cassowary of Australia.

Order 4. Dinornithiformes. Large flightless birds without keel ; reduced sternum and wing bones; which have become extinct a few centuries ago. Example : *Dinornis* the moas of New Zealand.

Order 5. Aepyornithiformes. Large flightless birds with broad, short unkeeled sternum, extinct for several centuries. Example : *Aepyornis* the elephant bird of Madagascar.

Order 6. Apterygiformes. Flightless birds; long, slender beak with the nostrils at the tip : wing rudimentary ; unkeeled sternum; toes four. Example : *Apteryx* the kiwi of New Zealand (Fig. 338)

Superorder iii. NEOGNATHAE. Toothless modern birds with keeled sternum, well developed wings, pygostyle, fused metacarpals.

Order 7. Sphenisciformes. Wings modified into paddles for swimming ; incompletely fused metatarsus ; toes four and completely webbed ; feathers scale-like ; stand erect and swim by the paddles. Example : *Aptenodytes forsteri* the emperor penguin of Antartica (Fig. 339).

Order 8. Procellariiformes. Oceanic birds with narrow and long wings tubular nostrils. Example : Albatross.

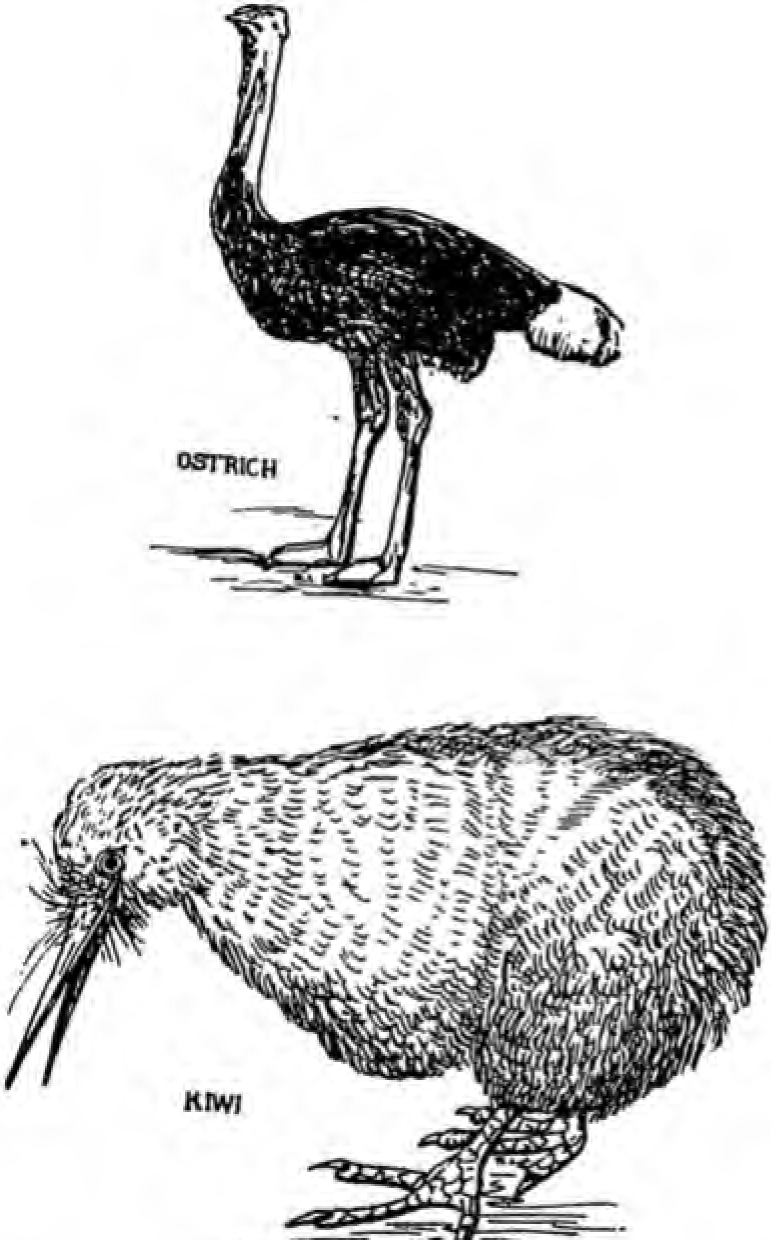


FIG. 338. Subclass Neornithes. Palaeognathae. The ostrich stands eight feet high and weighs three hundred pounds. The wings are degenerate but the legs are well adapted for fast running. During the breeding season the hen "sits" on the eggs by day and the cock by night. Ostriches occur in Africa. The kiwi is a nocturnal bird found in New Zealand. It feeds on worms, grubs and beetles. The wing is reduced. Only the cock incubates the eggs.

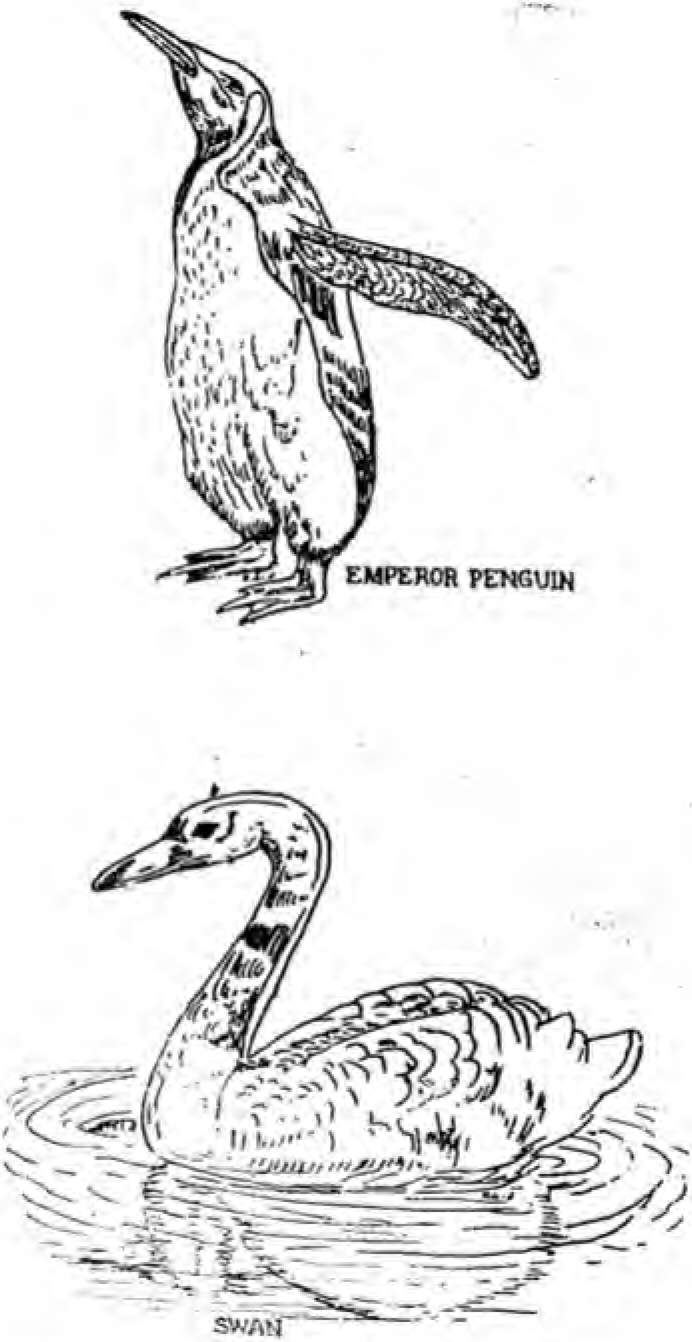


FIG. 339. Subclass Neornithes. Neognathae. Order Sphenisciformes. The emperor penguin has a very restricted range and is confined to the far Antarctic. Never once does it come on dry land but when not swimming stands on ice. The wings have become modified as paddles. Penguins live in great colonies. Order Anseriformes: The swan is beautifully adapted for swimming.

FIG. 340. Subclass Neornithes. Neognathae. Order Ciconiiformes. The heron stands on one leg among the reeds of some quiet river or lake, waiting for fish.

FIG. 341. Subclass Neornithes. Neognathae. Order Passeres. *Corvus splendens* the common house crow is with us from very early dawn to night fall. He is a town-dweller and has many wily ways. He holds punchayats for punishing any crow for his uncorvine conduct.

Order 9. Pelicaniformes. Aquatic fish-eating birds with rudimentary nostrils, all the four toes webbed. Examples : Pelicans, Cormorants.

Order 10. Ciconiiformes. Wading birds with long legs and necks ; feed on fish, frogs, etc. Examples : herons, (Fig. 340) storks, ibises, flamingos.

Order 11. Anseriformes. Aquatic birds with broad bills and webbed toes on short legs. Examples : *Anas* ducks, (Fig. 339) geese, swans.

Order 12. Falconiformes. Carrion feeders with stout beak hooked at tip, sharp curved claws for tearing flesh; scavangers; diurnal birds of prey. Examples : Falcons, eagles, vultures, kites and hawks (Fig. 342).

Order 13. Galliformes. Ground birds with the feet adapted for scratching, short bill. Examples : grouse, partridge, pheasants, turkeys, domestic fowl, peacock.

Order 14. Gruiformes. Wading birds of marshes, with toes partially webbed ; long neck. Example : crane.

Order 15. Columbiformes. Beak short, with soft thick skin at base; crop producing the so-called "pigeon-milk" for the young. Examples : Doves and pigeons.

FIG. 342. Subclass Neornithes. Neognathae. Order Falconiformes. Vultures have gruesome habits and feed on carrion. They have very sharp vision and can see dead bodies from an altitude of more than a thousand feet.

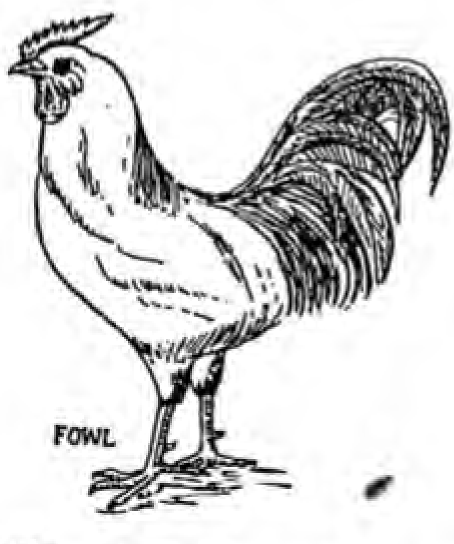


FIG. 343. Subclass Neornithes. Neognathae. Order Coraciiformes: Owls are nocturnal birds, with eyes that look forward and have a curious arrangement of feathers in a circle round them. Some believe them to be capable of perceiving infra-red rays. Order Galliformes: The common domestic fowl is derived from the jungle fowl *Gallus bankiva*.

Order 16. Cuculiformes Toes 2 in front and 2 behind; not adapted for grasping; tail short: female smuggles her eggs into the nests of other birds, which incubate them. Examples: cuckoo or koil.

Order 17. Psittaciformes. Toes 2 in front and 2 behind and adapted for grasping; beak stout and hooked; fleshy tongue, may learn to talk; plumage brilliant green, red, yellow or blue; voice loud. Example: parrots.

Order 18. Strigiformes. Nocturnal birds with large eyes directed forwards and surrounded by radial feathers; short bill; sharp claws. Example: Owls (Fig. 343).

Order 19. Micropodiformes. Small birds with very short legs, pointed wings, tubular tongue. Examples; swift; humming bird (wholly American).

Order 20. Coraciiformes. Bill strong; 3rd and 4th toes fused basally. Examples: bee-eater, hoopoep, hornbill, kingfisher.

Order 21. Piciformes. Beak stout and chisel-like for digging into wood; rough and barbed tongue. Example: woodpecker.

Order 22. Passeriformes. Toes 3 in front and 1 behind adapted for perching. Most birds. Examples; swallow, crow, wren, robin, oriole, lark, sparrow.

FIG. 341. Subclass Neognathae. Order Coraciiformes. Kingfisher dives from a stationary perch and catches fish with its beak. The fish is stunned by being beaten against the branch before swallowing.

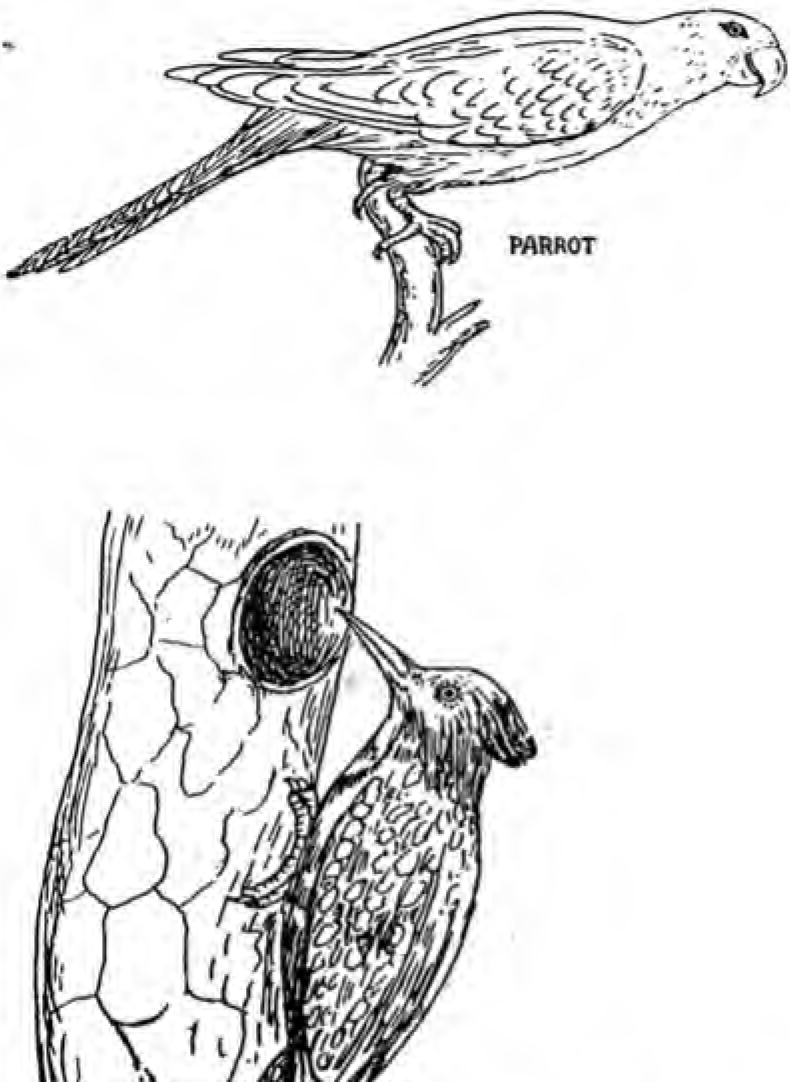


FIG. 345. Subclass Neornithes. Neognathae. Order Opisthocomiformes Psittaci: The parrot has the jaws adapted for climbing and for slicing fruits or breaking nuts. It is a good talker and can also perform tricks. Order Coraciiformes : woodpecker has excessively long tongue, covered with sticky saliva, that can be thrust into wood for picking insects within.

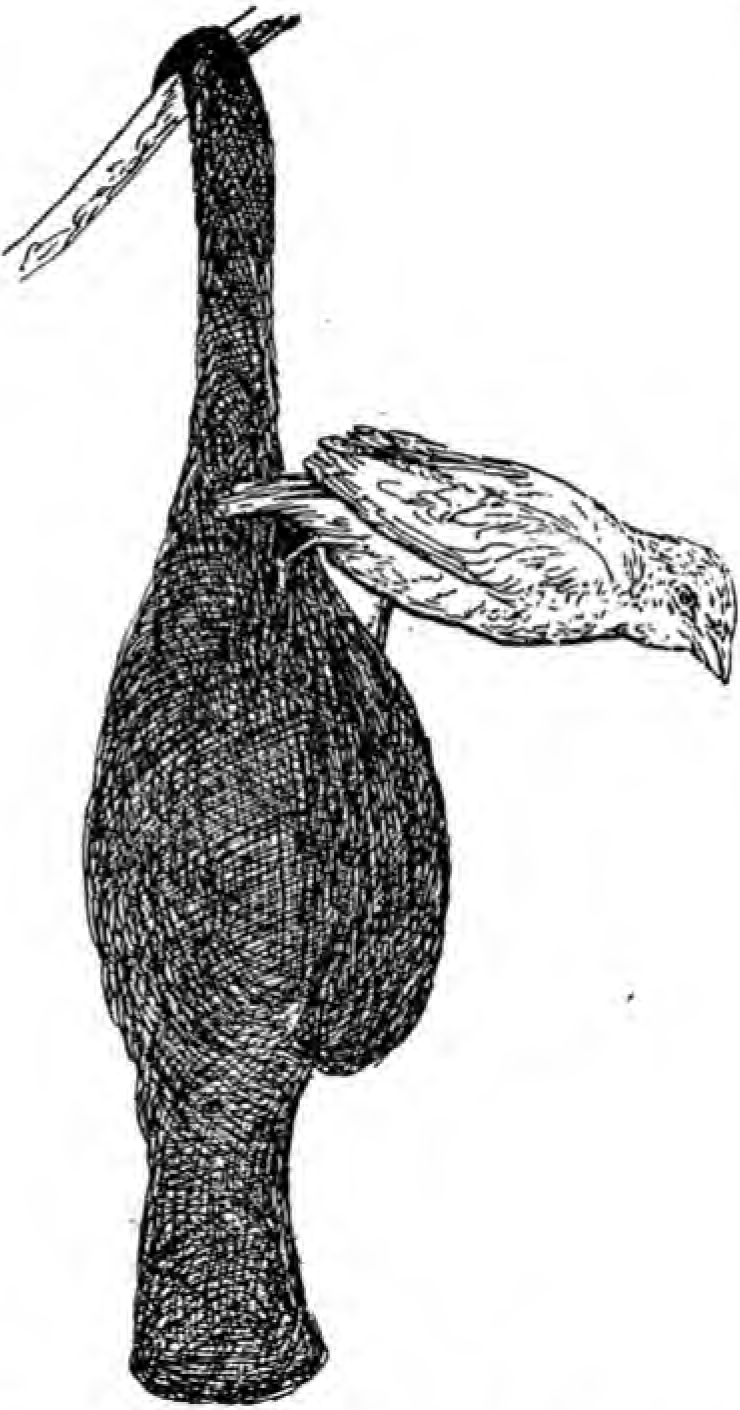


FIG. 346. Subclass Neornithes. Neognathae. Order **Passeriformes.** *Ploceus* the common weaver bird of India weaves its nest of fibres on *Acacia* trees.

Structure

EXTERNAL: The body is divisible into head, neck, trunk and tail. It is covered by feathers. A typical feather (Fig. 347) is composed of a ***quill***, continuing as the ***shaft*** that bears ***barbs***. The barbs bear ***barbules***. The barbs lie parallel, so that the barbules interlock, thus forming a ***vane***. When the barbs form a confused fluff we have a ***down*** feather. The feathers are not scattered at random but are distributed in certain definite ***feather tracts***.

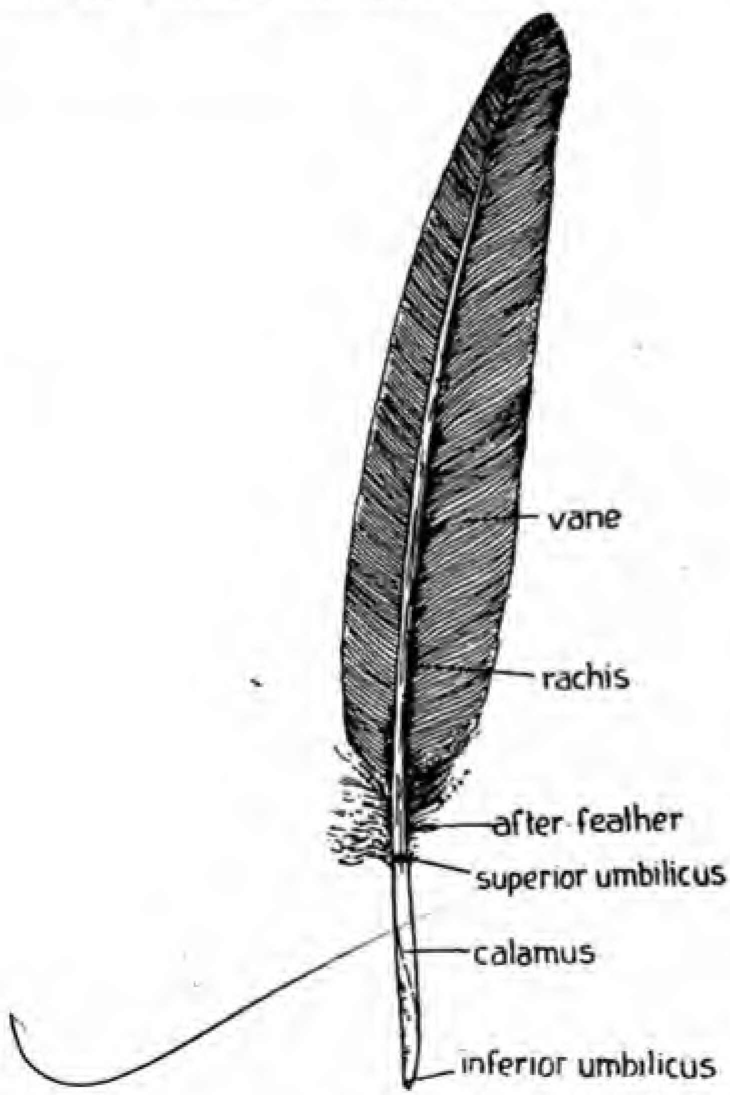


FIG. 347. Wing feather of a bird.

The fore limb is slender and modified as wing. It is covered by feathers; especially along the posterior margin the feathers make up the surface of the wing. The hind limb supports the body weight when the bird is on the ground and is used in walking, running, scartching, grasping,

climbing or swimming. Typically it has four toes, three in front and one behind. The thigh and more or less of the lower leg are covered by feathers The rest of the leg is covered by scales. This scale-covered part is thin and has no muscle but contains only the long tendons passing down from the muscles above to the toes. The true tail is short and hidden beneath the feathers but it bears a number of long ***tail feathers,*** which serve as rudder.

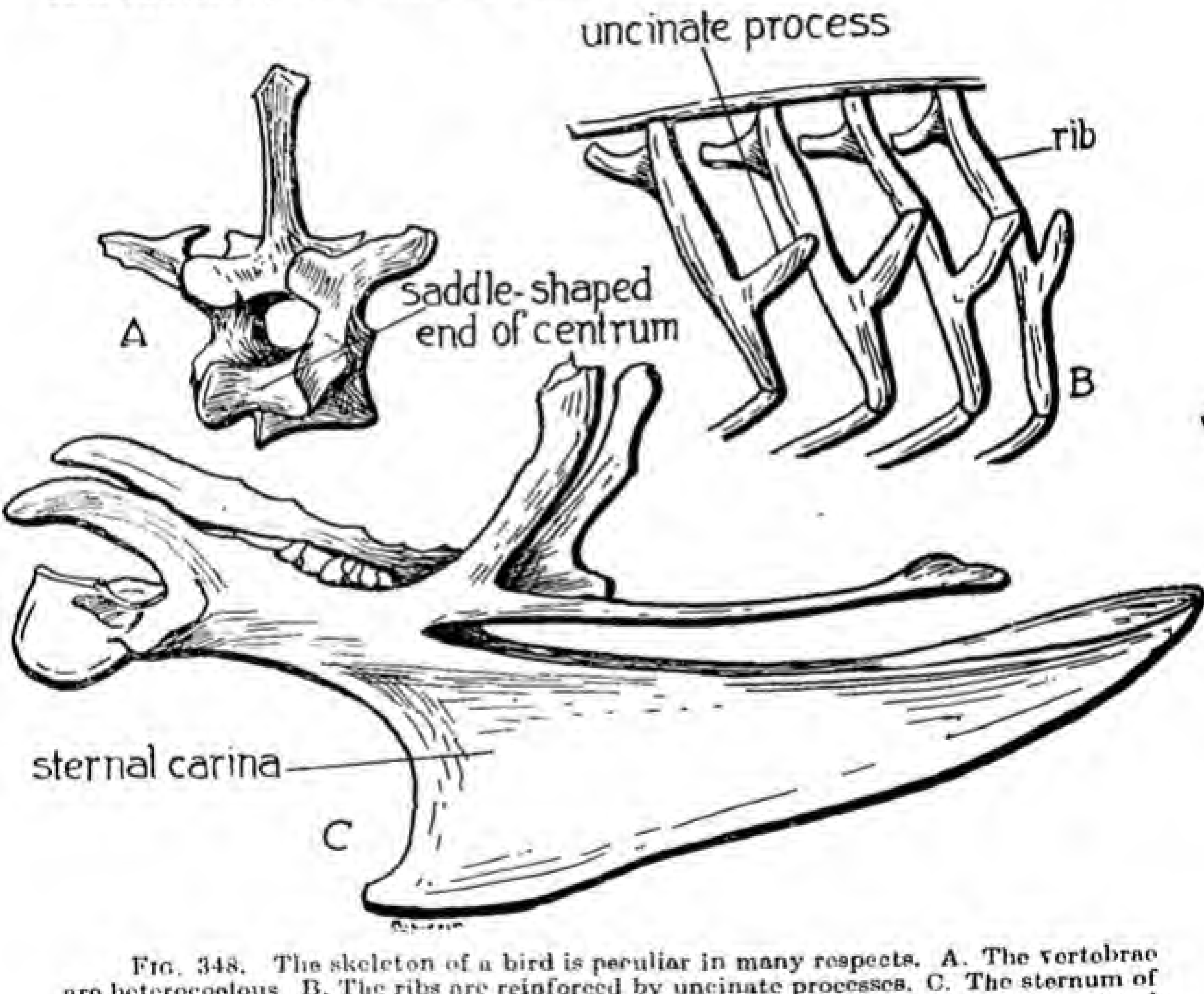


Fig. 348. The skeleton of a bird is peculiar in many respects. A. The vertebrae are heterocoelous B. The ribs are reinforced by uncinate processes. C. The sternum of flying birds has a huge bony crest or carina for attachment of the great pectoral muscles that move the wings.

INTERNAL: The skeleton is rigid; many bones of the head, the vertebrae, ribs, etc., are fused. The vertebrae have ***heterocoelous*** centra: the centra have saddle-shaped ends. Each rib is braced by an ***uncinate*** process passing behind to the next. The bones are also light and contain air spaces. The sternum has a conspicuous ***keel*** or ***crest,*** from which arise the muscles that move the wings.

In most birds, especially seed-eating ones, the oesophagus is greatly enlarged into a ***crop.*** The stomach comprises an anterior ***proventriculus*** in which the gastric juice is produced, and a posterior ***gizzard*** in which the food is ground. Birds swallow small stones which help in this grinding. The intestine continues to the cloaca.

The heart is large and is completely partitioned: there are two auricles and two ventricles. The venous blood from the right auricle flows to the right ventricle, thence through the pulmonary artery to the lungs. The oxygenated blood returns by pulmonary vein to the left auricle. From here it flows into left ventricle and thence through the aortic arch to the dorsal aorta. There is *only one* aortic or systemic arch: it is on the *right side.* There is a well developed hepatic portal and a reduced renal portal system.

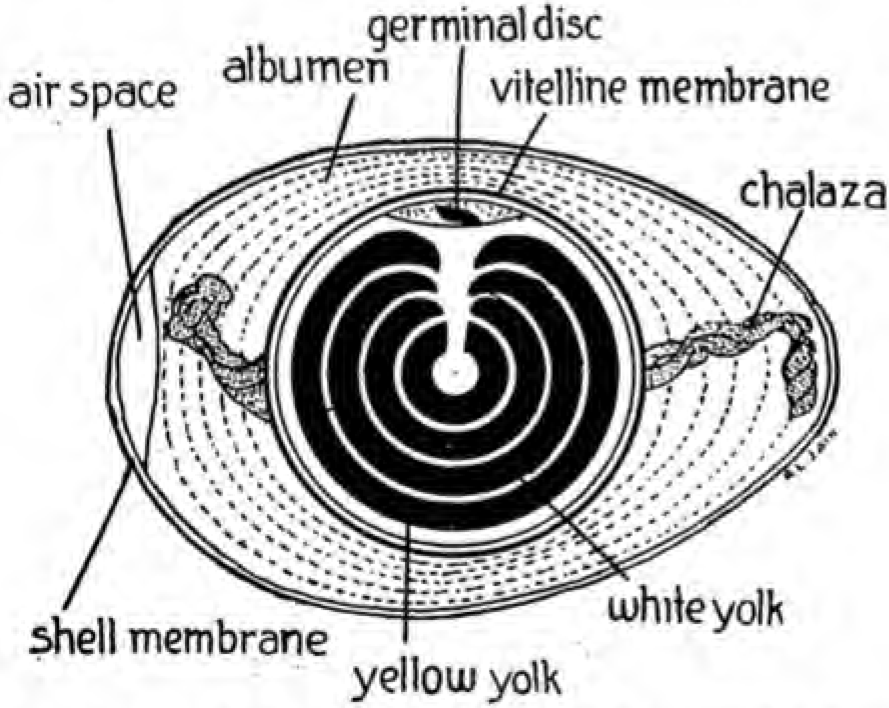


FIG. 349. Diagram of the structure of a hen's egg at the time it is deposited.

Lungs are connected to numerous ***air sacs*** among the muscles and other parts. When the bird is flying, the contraction of the muscles causes the renewal of the air in the air sacs and lungs. The bird thus breathes more easily when flying than when at rest.

The body temperature is rather high. It varies between 105° F. to 115° F. There is no urinary bladder. The ***urates*** pass directly into the cloaca. Only the *left* ovary is present in the adult bird.

Birds have poor olfactory sense but well developed sense of sight. The large eyeball is proportionately larger than in any vertebrates. The sclerotic coat is reinforced by bony plates. There is a peculiar comb-like structure, the ***pecten*** of unknown function in the vitreous humour.

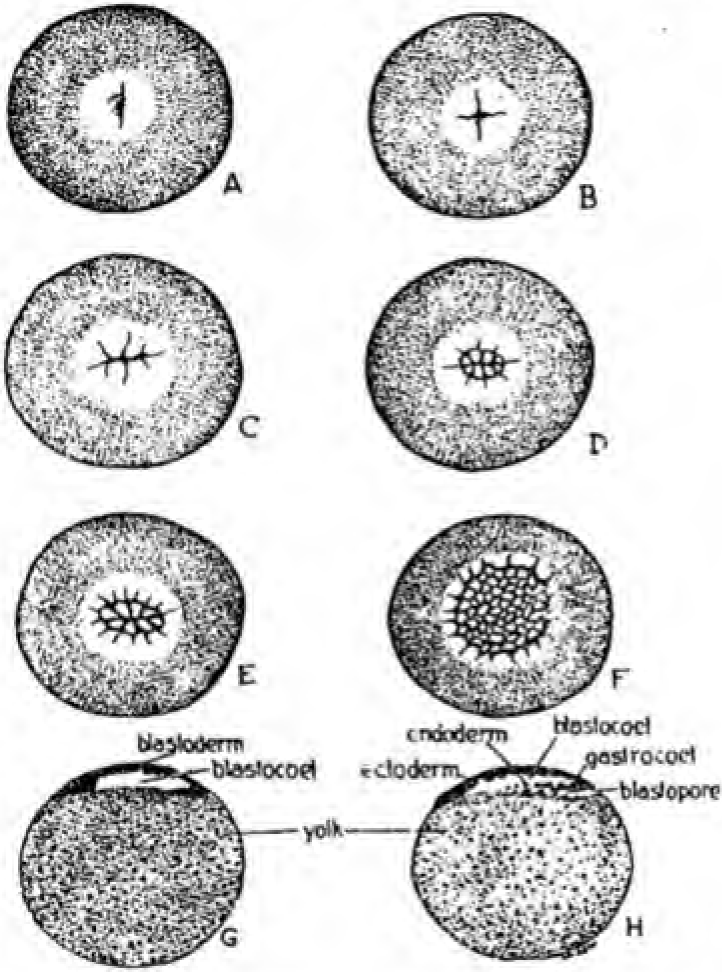


FIG. 350. Early embryonic development of the chick. A. First cleavage. B.—E. Successive stages in the cleavage. F. Bastodisc at the end of cleavage, viewed from above. G. Vertical section of blastula. H. Vertical section of early gastrula.

Flight.—Birds fly in different ways. In ***sustained flight*** they strike the wings downward and forward. After several strokes, the wings may be held motoinless. The bird then ***glides*** a considerable distance before the wings are again beaten. Some birds like the kites describe great circles at high altitudes, rising with each circle but with the wings motionless. This is the ***soaring*** flight. Others remain poised in air, beating the wings—they ***hover***.

Flight adaptations.—Every structural feature of the bird is an adaptation for flight. The body of a bird is streamlined to reduce

obstruction in flight The fore limbs are modified into wings. Lightness of body is achieved by the ***pneumaticity*** of the bones. Steering and balancing are effected by the tail feathers.

FIG. 351. Dorsal view of the entire chick embryo of about 16 hours incubation

Development

THE EGG (Fig. 349): In birds the fertilization is internal. The ovum is fertilized during its entry into the oviduct. The egg of a bird is thus really a ***zygote***. As the zygote passes downwards, the ***albumen***, the ***shell membrane*** and the ***shell*** are secreted around it. The upper part of the oviduct secretes the stringy albumen, which adheres to the ***vitelline membrane***. The egg rotates as it moves downwards and the albumen becomes twisted into the ***chalazae***. The chalazae capture the further albuminous material that is secreted in

concentric layers. The shell membrane is added further downward in the oviduct and finally the shell is secreted. The structure of the egg at the time of laying is shown in the figure.

There are two kinds of yolk: ***white yolk*** and ***yellow yolk.*** The white yolk is also immediately under the vitelline membrane. The chalaza serves to suspend the yolk in the albumen. The two layers of shell membrane enclose an air space at the large end of the egg. The shell is largely calcareous. It is porous so that exchange of the gases necessary for embryonic respiration is possible.

FIG. 352. Dorsal view of the entire chick embryo of about 24 hours incubation. Four pairs of mesoblastic somites.

The development of the egg that has been laid ceases unless the egg is kept at a temperature nearly equal to that of body of the mother, that is, ***incubated.*** For this purpose the mother "sits over" the eggs or broods them. The eggs can also be artificially incubated at about 37° C. The egg fails to develop below 21° C.

Cleavage, Blastula and Gastrulation.—(Fig. 350) The immediate result of fertilization is repeated mitotic division of the zygote or ***cleavage.*** Cleavage takes place as the egg is passing down the oviduct.

The large size of the egg is due to the great quantity of yolk or *deutoplasm*. Deutoplasm is inert, non-living material and therefore takes no part in cleavage. The protoplasmic part is crowded as a tiny

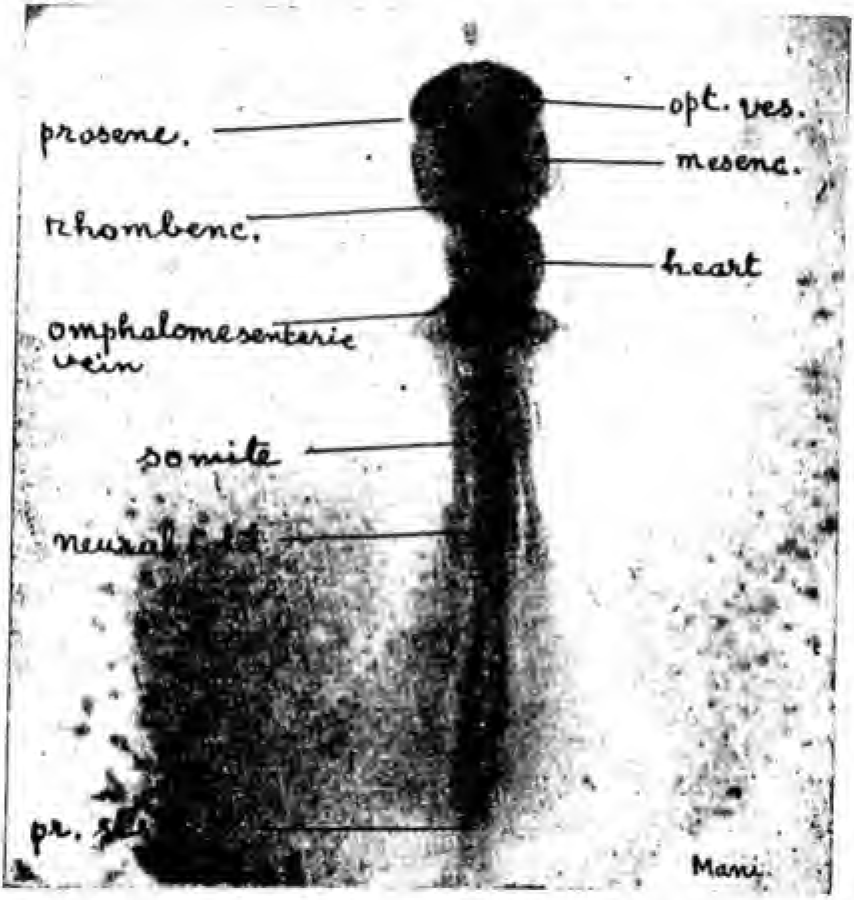


Fig. 353. Dorsal view of the entire chick embryo of about 33 hours incubation, with about a dozen pairs of mesoblastic somites.

blastodisc or germinal disc at one end, the ***animal pole,*** as distinct from the ***vegetative pole*** or the deutoplasmic part. Such a polar differentiated egg is called ***telolecithal*** ovum. The cleavage in such an egg is confined only to the animal pole and yolk remains entirely undivided. Such an egg is described as ***meroblastic.*** The result of cleavage is the formation of the ***blastoderm,*** a disc of ***blastomeres*** that floats on the yolk. The segmentation is thus ***discoidal.***

The centre of the blastoderm becomes detached from the yolk beneath, thus creating a space, the ***blastocoel.*** The margin of the blastod erm remains attached to the yolk. The embryo is now a ***blastula.***

The blastula of the bird differs from that of the frog in not being a hollow sphere. Further, the floor of the blastocoel is formed by the yolk.

The gastrulation (Fig. 350, H.) in birds is modified by the presence of a large amount of yolk. The narrowness of the blastocoel limits the extent of invagination. The cells of the free margin of the blastoderm

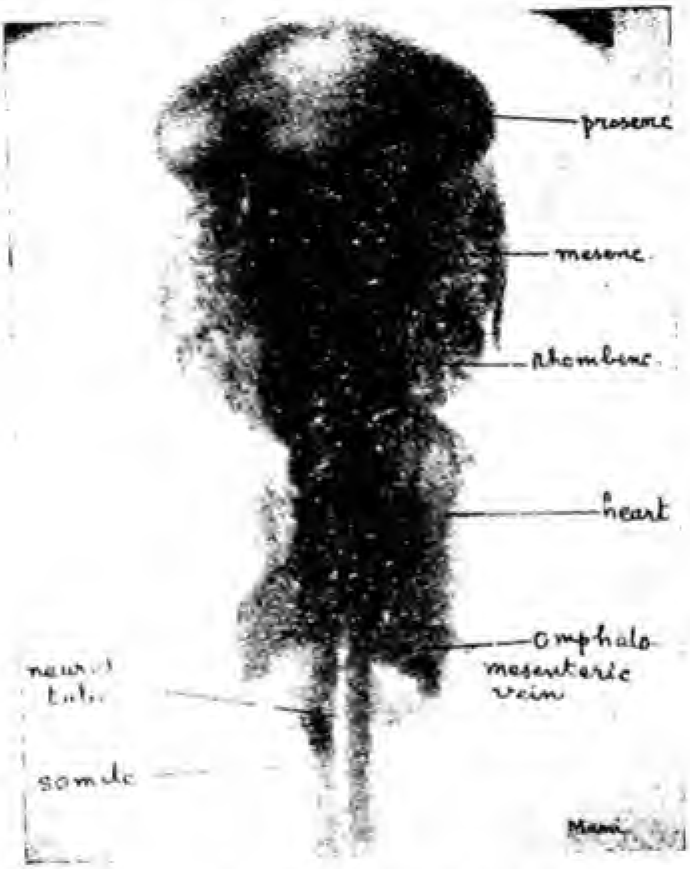


FIG. 354. Same as fig. 353, but anterior part highly magnified.

become tucked under or invaginated. The invaginated cells represent the ***endoderm***, extending from the ***blastopore*** to the front of the embryo. The yolk forms the floor of the ***gastrocoel***. During gastrulation the blastoderm itself slowly spreads over the periphery of the yolk. Anteriorly the lips of the blastopore fuse and thus give rise to the so-called ***primitive streak*** when viewed from the surface. When the egg is laid, gastrulation is already complete and the primitive streak is distinct in the hen's egg that has been incubated for 16 hours (Fig. 351).

Archenteron, notochord and mesoderm. – The endoderm soon becomes organized into a continuous layer. The gastrocoel is now termed ***archenteron***. In sections the embryo is removed from the yolk, which forms the floor of the archenteron ; therefore the archenteron on

slides looks as if it had no lower boundary. The notochord and mesoderm arise together. The former is first seen in the embryo incubated for about 20 hours, extending forwards from the ***Hansen's node*** or the anterior end of the primitive streak. The mesoderm arises from either side of the primitive streak and spreads laterally. Later it splits into two layers, one of which is the ***somatopleure*** and lies next to the ectoderm, the other is the ***splanchnopleure*** which lies next to the endoderm Between these two layers is the ***coelom***.

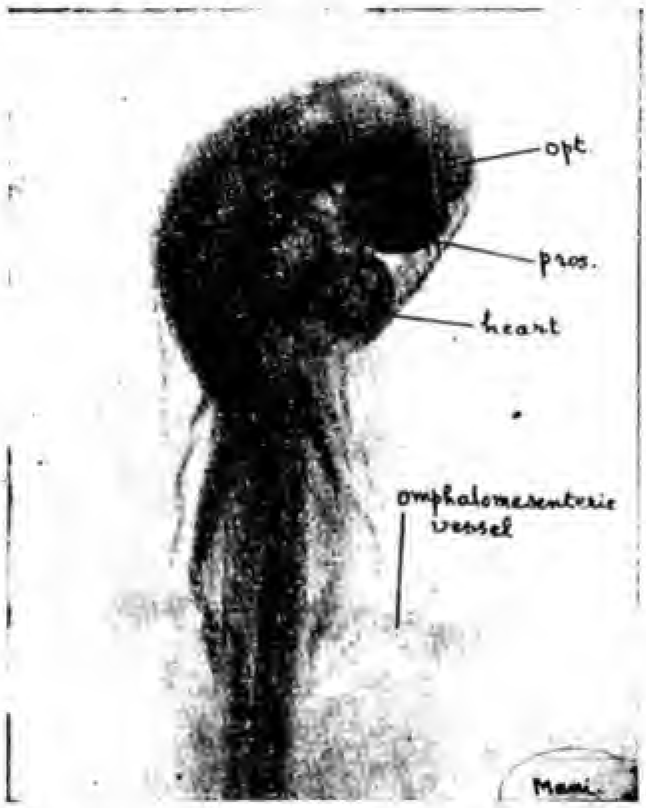


FIG. 355. Dorsodextral view of the entire embryo of chick of about 48 hours incubation.

Neural plates.—The ectoderm above the notochord becomes thickened into the ***medullary*** or ***neural plate***. The neural plate then folds longitudinally to form a ***neural groove***. On either edge of the neural groove are ridge-like elevations or ***neural folds***. The neural groove is deeper anteriorly than elsewhere. Finally the neural folds approach each other and fuse to enclose the ***neural tube***, lying below the ectoderm. In the 27 hours old embryo the neural tube enlarges anteriorly. This part is destined to develop into the brain. The undilated part of the neural tube develops into the spinal cord. The enlarged part shows three vesicles: ***prosencephalon***, ***mesencephalon*** and

rhombencephalon. The prosencephalon bulges out laterally to form the ***optic vesicles,*** that develop into the eye.

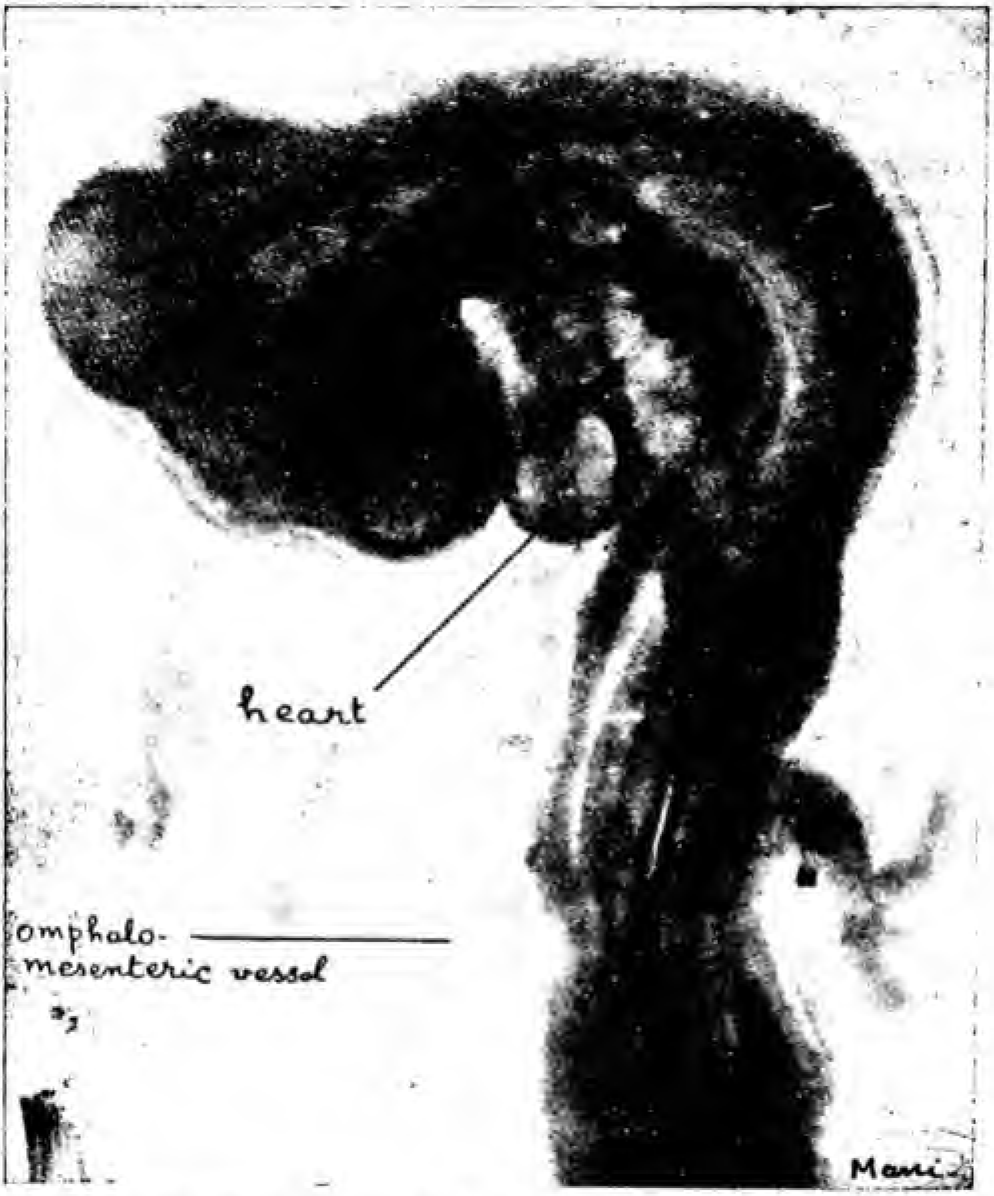


FIG. 356. Dorsosinistral view of the entire embryo of chick of about 72 hours incubation.

The Differentiation of Embryonal Field.—The blastoderm grows round and gradually spreads over the yolk. It is however only a small part of the blastoderm, immediately surrounding the primitive streak, that gives rise to the nerve tube, notochord and other organs. This part is termed the ***embryonal area*** in contradistinction to the ***outer-embryonal area.*** Although at first the embryonal area is directly continuous with the extraembryonal field without any definite

line of demarkation, they become folded off from each other at a later stage. The extraembryonal area is not built into the body of the embryo but contributes for the nutrition and protection of the embryo.

The embryonal field becomes thick anteriorly and projects as a globose elevation from the general surface of the blastodisc. This elevated region marks place of development of the head In embryos incubated for about 22 hours it is bounded anteriorly by a crescentic fold. In about 24 hours the head projects freely from the blastoderm. Both ectoderm and endoderm are involved in the outgrowth of the head. The endoderm projects into the ectoderm; this projection represents the fore gut, which is thus also the first part of the digestive tract to acquire a cellular floor.

Embryonal membranes.—The embryonal membranes are ***yolk sac, serosa, amnion*** and ***allantois.*** They are embryonal organs that serve for protection, nutrition and respiration. Yolk sac, amnion and serosa originate in the extraembryonal field. Allantois develops from within the embryo. Like the ectoderm (originally the blastoderm) the mesoderm and endoderm also extend into the extraembryonal region. The splanchnic layer of the mesoderm does not form the floor of the gut but grows round over the surface of the yolk and forms the ***yolk sac***. The absorption of the enclosed yolk is effected by the epithelium (endoderm) of the yolk sac The extraembryonal somatopleure of the mesoderm grows over the head and becomes doubled as the ***amniotic fold***. The first indication of this becomes visible in the chick embryo incubated for about 30 hours. The amniotic fold or the doubled up extraembryonal somatopleure gradually extends backwards over the embryo. On the third day in the caudal region also similar amniotic fold (of doubled up extraembryonal somatopleure) and lateral folds grow forward over the embryo. Finally the amniotic folds unite together, thus completely enclosing the embryo in the double membrane: the inner ***amnion*** and the outer ***serosa***. The amnion encloses an ***amniotic cavity***, filled with the ***amniotic liquid***. The cavity between the serosa and amnion is ***extraembryonal coelom***. The liquid filled spaces serve to absorb shocks and also act as "swimming pools" for the embryo. The serosa extends right up to the yolk sac stalk.

Allantois (Fig. 357) first appears late on the third of incubation as a diverticulum from the ventral wall of the hind gut. It is lined by an extension of the embryonal splanchnopleure and corresponds to the

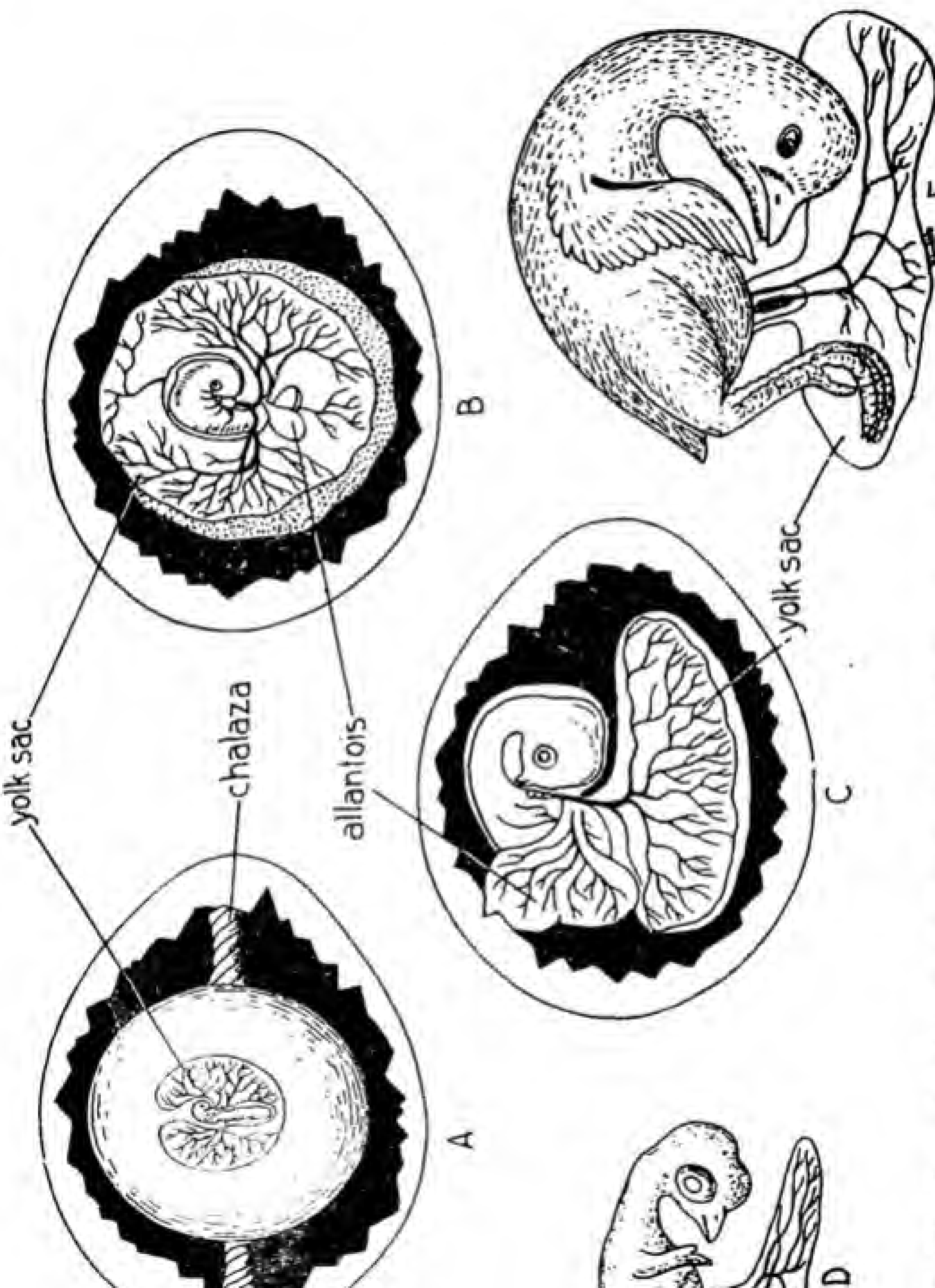


FIG. 357. Formation of the yolk sac and allontois during the embryonic development of the chick. (*From Duval, Atlas d'Embryologie*, 1889).

urinary bladder of the frog. On the fourth day of incubation the allantois projects out of the body into the extraembryonal coelom and becomes enlarged at the free end. It is filled with the ***allantoic fluid***—the nitrogenous wastes from the embryo. It spreads and finally on the ninth day encloses the whole embryo, amnion and the yolk sac. It becomes rich in blood vessels. Its primary function is to ensure the supply of oxygen of the blood of the embryo but it also acts as a store for the excretory products of the embryo and further helps in absorption of the albumen. It is thus an extraembryonic bladder and lung.

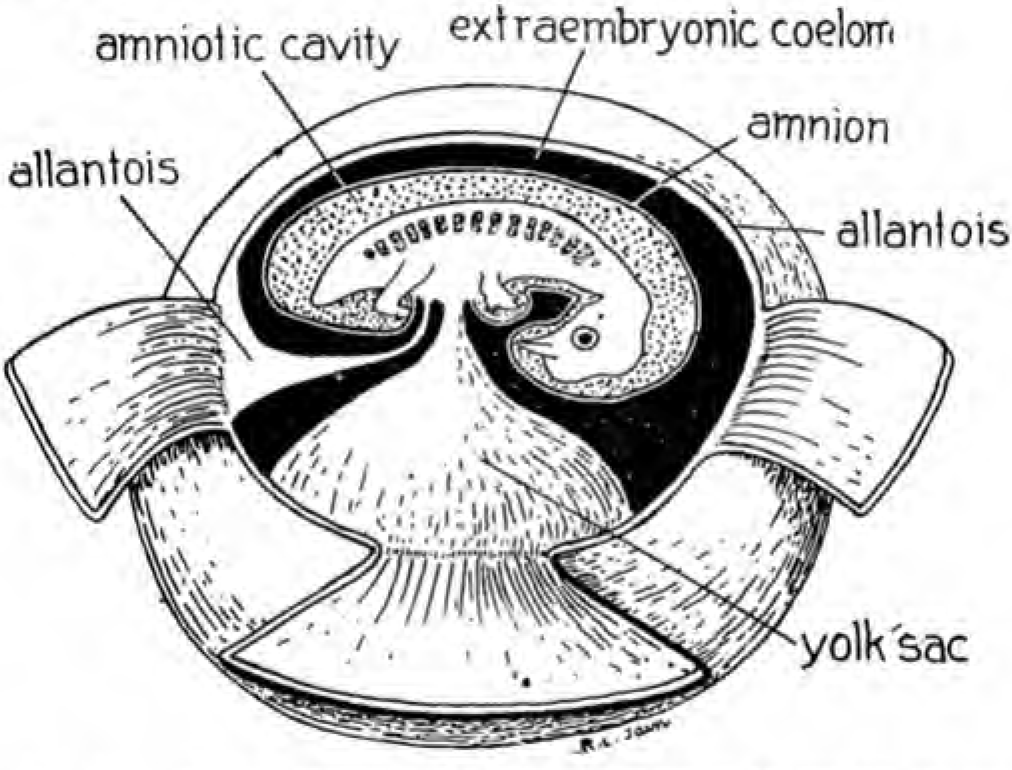


FIG. 358. Diagram showing the relation of the serosa, the amnion, the allantois and the yolk sac to the chick embryo.

Blood vascular system—The heart arises as paired tubes formed from splanchnic mesoderm. The tubes soon fuse into a single median tube connected with ***ventral aorta*** in front and ***vitelline veins*** behind. The median tube becomes bent and twisted on itself at about 33 hours of incubation and commences beating when the embryo has been incubated for 44 hours. The separation of the left and right chambers is completed in the first week of incubation. Six aortic arches appear at first. The first and second disappear on the third and fourth days of incubation. The third arch forms a part of the carotid artery. The fourth

arch disappears on the left but remains on the right as the ***systemic*** arch. The fifth disappears and the sixth arch gives rise to the pulmonary arteries. The ***vitelline veins*** unite together and form the ***hepatic*** vein.

Hatching.—An embryonic 'tooth' or the hard horny tip of the bill pierces the shell and the young bird comes out. The embryonal envelops are left behind. The young of some birds like the fowl and duck are fully formed, covered by down feathers and are able to run about directly after hatching. They are ***precocial***. The young of songbird, pigeons, woodpeckers and others are naked, blind and helpless when hatched. They are fed and cared by the parents in the nest; they are called ***altricial***.

Events during the early development of the chick

1. EMBRYO INCUBATED FOR 12-16 HOURS —
   - (*a*) Primitive streak becomes distinct by closure of blastopore.
   - (*b*) Gastrulation complete.
   - (*c*) Archenteron differentiated; with a roof of endoderm and floor of yolk
2. EMBRYO INCUBATED FOR 18-22 HOURS—
   - (*a*) Notochord extends forward from Hansen's node.
   - (*b*) Neural plate becomes converted into neural groove, with neural folds.
   - (*c*) Anterior end of the embryonal area projects above the general surface of the germinal disc, marking the site of differentiation of head.
3. EMBRYO IMCUBATED FOR 24 HOURS—
   - (*a*) Formation of head.
   - (*b*) Neural groove deepens.
   - (*c*) Mesoderm divides and coelom appears.
   - (*d*) Pericardium differentiated.
4. EMBRYO INCUBATED FOR 36 HOURS—
   - (*a*) Neural groove closes to form the neural tube.
   - (*b*) Neural tube dilates anteriorly to form the brain.
   - (*c*) Primitive streak disappears.
   - (*d*) Fore gut elongates.
   - (*e*) Heart and omphalomesenteric veins appear.
   - (*f*) First indications of amnion.
   - (*g*) Auditory plate develops.

) INCUBATED FOR 48 HOURS—

he head region sharply flexed ventrally.

'itelline circulatory channels completed.

;lood circulation begins: heart starts beating, it is a U-shaped tube.

Amnion develops about the caudal region.

First indication of allantois.

IBRYO INCUBATED TO 50-55 HOURS—

ı) Head freed from yolk.

b) Cranial flexure progresses far, so that the brain is nearly bent double on itself.

(c) Optic cup differentiated.

(d) Lens arises.

(e) Fore gut advanced and differentiated into pharynx and oesophagus.

(f) Stomodaeal invagination initiated.

(g) Hind gut first appears.

(h) Visceral arches and gill slits clear.

(i) Heart becomes looped.

(j) Two pairs of aortic arches.

(k) Dorsal aortae fuse into a single vessel.

*. EMBRYO INCUBATED FOR 72-96 HOURS —

(a) Amnion appears.

(b) Four visceral arches and slits appear.

(c) Appendage buds.

(d) Allantois enlarges on the fourth day.

(e) Eyeball defined.

(f) Mouth opens.

(g) Thyreoid gland develops.

(h) Trachea indicated.

(i) Lung buds off from the gut.

(j) Liver and pancreas appear.

(k) Wings and legs become differentiated.

(l) Gill slits open.

8. ON THE FIFTH DAY OF INCUBATION—Cartilagenous elements of the skeleton disappear.

9. ON THE NINTH DAY OF INCUBATION—

(a) Feathers develop.

(b) Allantois completely fills the extraembryonic coelom.

10. ON THE TWENTIETH DAY OF INCUBATION—The beak of the chick punctures the inner shell membrane. The embryo breathes air.

11. ON THE TWENTY-FIRST DAY—The chick hatches.

Natural history

COURTSHIP AND NEST-BUILDING: There is more or less elaborate courtship among birds. The males have often brighter plumage. They can sing to attract the mate. After mating, the birds build nests. Both the male and female frequently take part in nest-building. The nests are made of all sorts of materials. They range from crude affairs of sticks, stones and other rubbish to highly skilful nests. Crows, kites and others build very crude open nests of sticks. The weaver bird (Fig. 346) and the tailor bird on the other hand construct very elaborate, neat and artistic nests of fibres or leaves.

Ploceus philippinus, the common weaver bird of India, suspends its large and conspicuous nest of fibres (Fig. 346) from the tip of the slender palm shaft or branch of the babul tree. Nest building begins with the onset of rains. The birds tear off narrow strips of leaves of grasses, palms, etc. These strips are securely wound around the branch from which the nest is to be suspended, till a long stalk results. The birds now expand the lower part of the stalk into a bulb-shaped hollow structure. An egg-chamber is separated off from the entrance tube. Up to this time, both the male and female have collected the fibres and helped each other in weaving. Henceforth, the female stays inside, while the cock goes forth for bringing more fibres. He works from outside and she works from inside, both thoroughly enjoying themselves, singing all the time.

Orthotomus sutorius, the common Indian tailor bird, is remarkable for the skill which it displays in the construction of its nest. It actually sews together the edges of large-sized leaves to produce a cup, in which the nest is made of cotton. The female bends the leaf till the edges meet. She then makes a series of punctures along each margin of the leaves with her sharp beak. She now flies off to return with a strand of cobweb. She winds one end of it round the narrow part of the leaf. The loose end of the cobweb is carried across under the surface of the leaf to a puncture on the opposite side and attached. The rest of the punctures are also connected together in the same way. Cotton is drawn into threads, which are pushed through the punctures and thus the leaf edges are firmly sewn together. The interior is then lined by cotton. It is the hen bird which constructs the nest. In the breeding season the tail of

the male becomes abnormally elongated. This tail may be an impediment to nest building or the fellow is too proud to work; he may be merely lazy The poor wife does all the work!

In the horn-bill we find a wonderful example of husband-and-wife co-operation. The grotesque-looking hornbills, *Anthracoceras*, show several peculiarities. When the nesting time arrives, the female enters a natural cavity in the trunk of a tree. She lays eggs in this cavity. The entrance hole is then almost closed down to a narrow slit by applying her droppings. The male feeds her through this slit regularly until after the young birds have hatched out. Finally the female hammers away with her beak at the entrance plug and escapes. Both the parents now take part in feeding the young.

MIGRATION: One of the great wonders of bird life is migration. A great many birds shift regularly from one region to another with change of seasons. ***Latitudinal migration*** is north-south and ***altitudinal migration*** is from the plains to the hills. Migrating birds have well established routes, which they follow generation after generation, travelling on "scheduled time". During migration some birds keep close to the ground, while others fly high up. Many follow landmarks like mountain ranges, sea-coasts, etc., but others pass over seas. It is not understood why birds migrate. The migratory birds breed in the coolest part of their range and spend the winter in the warmer countries The koel migrates south in winter and returns to the north in spring. The Arctic tern is however the greatest migrant. It breeds in the Arctic Region during the summer in the northern hemisphere. With the approach of winter it flies off south at about 200 miles per day to the Antarctic, where it is now summer. When it becomes winter in the Antarctic, it returns the same way again to the northern home, now in summer. Annually it journeys more than 20,000 miles.

Relation to man – Birds and their eggs serve as food in all parts of the world. Bird feathers are used as ornaments. The feathers of the golden eagle are used for ceremonial head-dress by the Red Indians of America. Ostrich feathers are valued all over the world for their beauty. Guano is an important fertilizer found on certain islands of the south Pacific, off the coast of Peru This consists of dried excreta of sea birds, deposited in layers often up to 100 feet thick. Homing pigeons have been employed from ancient days in army signalling. Several birds are of importance as scavengers. Some destroy injurious insects and are therefore beneficial to agriculture.

The myna for example takes a heavy toll of the injurious grasshoppers. Owls are extremely beneficial in that they kill rats and mice. Others like parrots destroy ripening grains, seeds and fruits and are therefore harmful.

In recent years aerial collisions of birds with aeroplanes have caused several serious and fatal air-crashes. For centuries man has kept birds as pets.

Resumé

I. Birds

1. The birds are structurally very similar to reptiles but differ in possessing feathers and in the fore limbs being modified as wings.

2. Birds are classified into Archaeornithes comprising the fossil *Archaeopteryx* or lizard-bird and Neornithes that includes all the modern birds.

3. The skeleton is characterized by its pneumaticity. There is a single occipital condyle. The vertebrae are heterocoelous. The sternum possesses a carina in most birds.

4. In many birds the oesophagus is enlarged into a crop and the stomach specialized into a proventriculus and gizzard.

5. The heart is completely four-chambered and only the right aortic arch is present.

6. The lungs are connected to air sacs in different parts of the body.

7. There is no urinary bladder and solid urates pass into the cloaca.

8. Only the ovary of the left side is present.

II. Embryology of the chick

9. The hen's egg is a zygote that is rich in yolk and has an albumen also.

10. Fertilization is internal. Cleavage is discoidal and when the egg is laid gastrulation is already completed.

11. The egg is incubated at the body temperature by the brooding hen. The archenteron is roofed by endoderm but the yolk forms its floor. Notochord appears after twenty hours of incubation.

12. The embryonal membranes include amnion, serosa, yolk-sac and allantois. The allantois serves as embryonic bladder and lung.

III Natural history of birds

13. Birds have developed great powers of courtship, nest building, parental care and singing. Some also learn to talk.

14. Many birds make annual journeys called migration. The laws that govern bird migration are not clearly understood.

15. The eggs and flesh of birds serve as food for man. The feathers of many are used as ornaments or in making quilts. Homing pigeons are greatly employed by the army. Several birds destroy injurious insects, vermin, etc. and do considerable good.

25/93

CHAPTER XXII

MAMMALIA – MAMMALS

What are mammals? MAMMALS are warm-blooded Vertebrates that possess a hairy covering on the body and mammary glands in the female for suckling the young with milk. They include man, monkeys, cow, horses, dogs, cats, bats, rats, elephant, whales, seals and numerous other "beasts" or "quadrupeds". The great development of the cranium and cerebellum provides for a high degree of co-ordination of all activities. Mammals have great powers of learning and have retentive memory. They are very much advanced over Reptiles in many respects, especially in the complete separation of arterial and venous blood streams and in development of the embryo within the uterus of the mother.

Characters.—

1. Skin rich in glands, e. g. sweat glands, sebaceous glands, scent glands and mammary glands.
2. Hairs arise from the skin.
3. Occipital condyles two.
4. Cervical vertebrae usually seven.
5. Teeth of different kinds and in sockets and are replaced once or twice.
6. Eyes with movable lids.
7. Ears with external pinna.
8. Heart completely four-chambered with only the *left* aortic arch.
9. Erythrocytes circular *biconcave* discs *without* nucleus.
10. Muscular diaphragm separates the thoracic chamber from the abdominal.
11. Urinary bladder present and does not usually open into the rectum.
12. There is usually no cloaca, the reproductive and excretory ducts open directly to the outside and not into the digestive tract.
13. Male copulatory organ penis; testes generally in scrotum outside the abdomen.
14. Ovaries of both sides developed.
15. Ova holoblastic, minute and deficient in yolk, and without shell.
16. Fertilization internal.
17. Development in a special part of the oviduct—the uterus; embryo fixed by *placenta* to the uterus for nourishment.
18. Embryonic membranes; yolk sac, amnion, serosa and allantois.
19. Young nourished by mother's milk.

Skin.—The structure of the skin is very characteristic of mammals. It is composed of an outer ***epidermis*** and an inner ***dermis***. The epidermis consists of several layers of epithelium. The deepest layer—the ***stratum germinativum*** or ***malpighium***—comprising columnar cells,

produces new flat cells above. The superficial layers are horny and compose the ***stratum corneum***. Hairs, nails, claws and horns are derived from the horny layer. The dermis is rich in blood capillaries, fat cells and nerves. The malpighian layer sinks deep into the dermis to form a deep pit, the ***hair follicle***. The skin is covered by hairs.

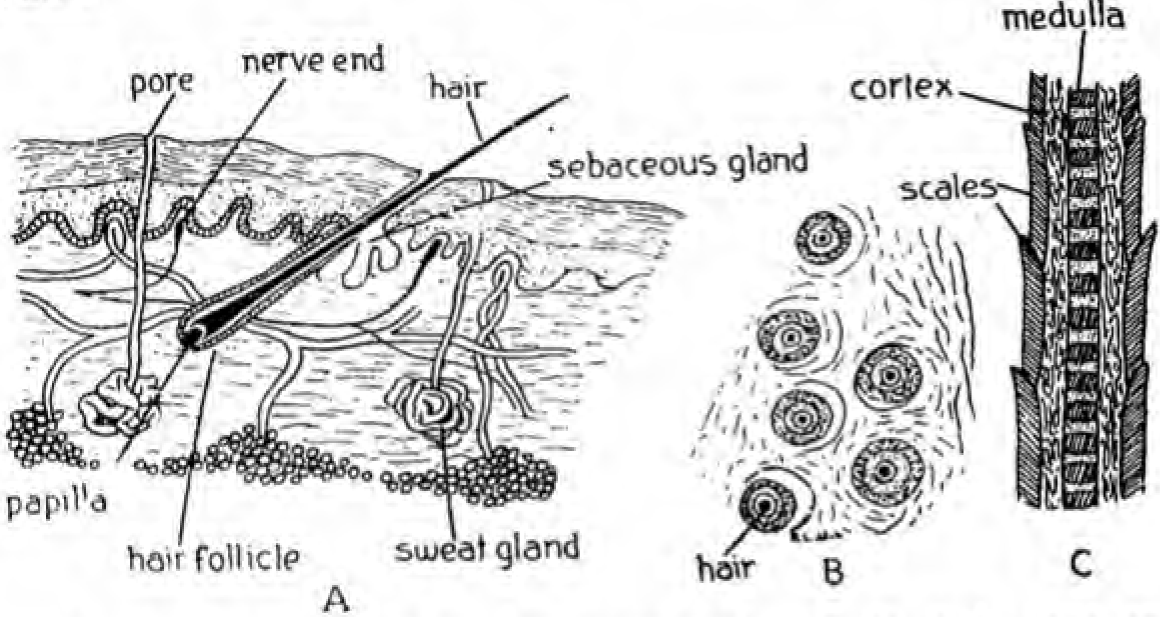


FIG. 359 Structure of the skin of mammals. A. Vertical section and B. Horizontal section through the skin. C. Longitudinal section through a hair.

Hairs.—OKEN called mammals as "hairy animals" because hairy covering is as much a distinguishing feature of mammals as feather is of birds. A "hair" is an unbranched epidermal structure, implanted in an invagination of the skin called the ***hair follicle***. It consists of a bulbous ***root*** in the hair follicle and an elongate ***shaft***. The root of the hair is enveloped by a ***root-sheath*** of double layer: an epidermal and an epithelial, and arises from a ***hair papilla*** in the bottom of the follicle. It is nourished by blood capillaries of the skin. Tiny muscles inserted at the base can erect the hair. The hair is composed of cornified cells. The shaft of the hair is externally covered by a thin ***pseudocuticle***, formed of imbricating scales Beneath this lies a fibrous ***cortex*** of elongated epidermal cells. In the centre is the ***medulla***. The principal function of the hair is to insulate body heat. As the hair follicles are provided with nerve-endings, hairs also serve as sensory structures. The ***sebaceous gland***, opening near the upper end of the hair follicle, secretes a fatty substance which lubricates the hair and prevents it from becoming dry and brittle.

All the hairs are collectively termed the ***coat*** or ***pelage***. The pelage varies in length, thickness, texture and colour in different mammals. It is very heavy in animals of the arctic lands and thin and short in tropical forms. Man, elephant, rhinoceros, hippopotamus and manatee are sparsely clothed with hairs. Whales have only a few bristles near the lips. Long sensory ***vibrissae*** occur about the nose and eyes of cats, rats and other animals. The quills of porcupines and hedgehogs are modified hairs. The so-called "horn" of the rhinoceros is a tuft of fused hairs.

Glands.—Another important character of the mammalian skin is its richness in glands. There are two kinds of cutaneous glands: ***sebaceous*** and ***sweat glands***. The sebaceous glands are associated with hairs and open into the hair follicle. The sweat glands are generally not associated with the hair. They are simple tubular glands opening on the surface by numerous pores and much convoluted at the base, which secrete the ***sweat***. The sweat regulates body temperature due to the cooling brought about by its evaporation from the body surface. The sweat is also an important excretory product.

These glands, especially the sebaceous glands, are modified into the scent glands as in musk rats and deers and nail glands as in cattle. The mammary or the milk glands are however the most important of these modifications. The mammary glands are the enormously developed, much branched and modified sweat glands. They are situated upon elevations of the skin known as ***teats***. In some mammals the teats are both on the thorax and abdomen: in others, as for example man, apes and monkeys only thoracic and in still others like the cattle only abdominal. In the male the teats and mammary glands are rudimentary and functionless.

Teeth.—The teeth of mammals differ from those of all other Vertebrates in varying widely in different parts of the jaws. The mammalian ***dentition*** is thus ***heterodont***. The anterior teeth, called ***incisors***, have sharp cutting edges. Behind them are the ***canines***, typically round and pointed for piercing and tearing. The canines are followed by ***premolars*** and ***molars***, provided with ***cusps*** for grinding. The incisors, canines and premolars are preceded by milk dentition but the molars are not; they only grow late in life.

The canines are absent in the herbivorus mammals like cattle and horse, leaving an empty space—the ***diastema***—between the incisors and premolars. In some mammals certain teeth become very

long to form ***tusks***. These are generally the enlarged incisors or canines and are usually found only in the males. The tusks of the elephant are for example enlarged incisors and those of the walrus the enlarged canines. Each mammal has a definite number of teeth expressed as ***dental formula***. The dental formula of man is I 2/2 C 1/1, P 2/2, and M 3/3; on each half of both the upper and lower jaws there are two incisors, one canine, two premolars and three molars, thus making a total of 32 teeth in all. The dental formula of the cow is I 0/3, C 0/0, P 3/3 and M 3/3.

The teeth of mammals are implanted in sockets in the jaws and are therefore described as ***thecodont***. There is also a succession of teeth. The teeth which develop during infancy constitute the ***milk teeth***, which fall off and are replaced by the ***permanent teeth***. Mammalian dentition is thus described as ***diphyodont***.

The teeth are homologically the placoid scales of the shark. They agree in structure and development. In each tooth there are three parts: 1. external enamel covered ***crown***, 2. a ***root*** buried in the ***alveolus*** or socket in the jaw bone and 3. a ***neck*** between the root and crown. The crown has one or more ***cusps*** or tubercles, the number of roots is also different.

A tooth consists of a central ***pulp cavity***, filled with connective tissue, rich in blood capillaries and nerves, surrounded by a hard bone-like substance, the ***dentine*** or ivory. The exposed surface is covered by ***enamel*** and the root by ***cement***.

Placentation.—Mammals differ from all other animals in that the embryo develops within the ***uterus***, a specialized part of the oviduct, of the mother. It derives nourishment and oxygen from the maternal blood. This mode of development is called ***intra-uterine***. The ovum of the mammals is minute, deficient in yolk and does not have a shell. It undergoes total and equal cleavage; it is thus ***holoblastic***. The blastoderm becomes differentiated into an embryonal and extra-embryonal area. As in birds, the extraembryonal area gives rise to the yolk sac, amnion and serosa. The allantois develops from the hind gut, extends into the extraembryonic coelom and encloses the whole embryo. It becomes highly vascular and is closely applied to the serosa. The two membranes constitute the ***chorion***. The chorion develops externally numerous branched ***allantoic villi*** (Fig. 360), which are richly supplied by blood vessels from the embryo. The

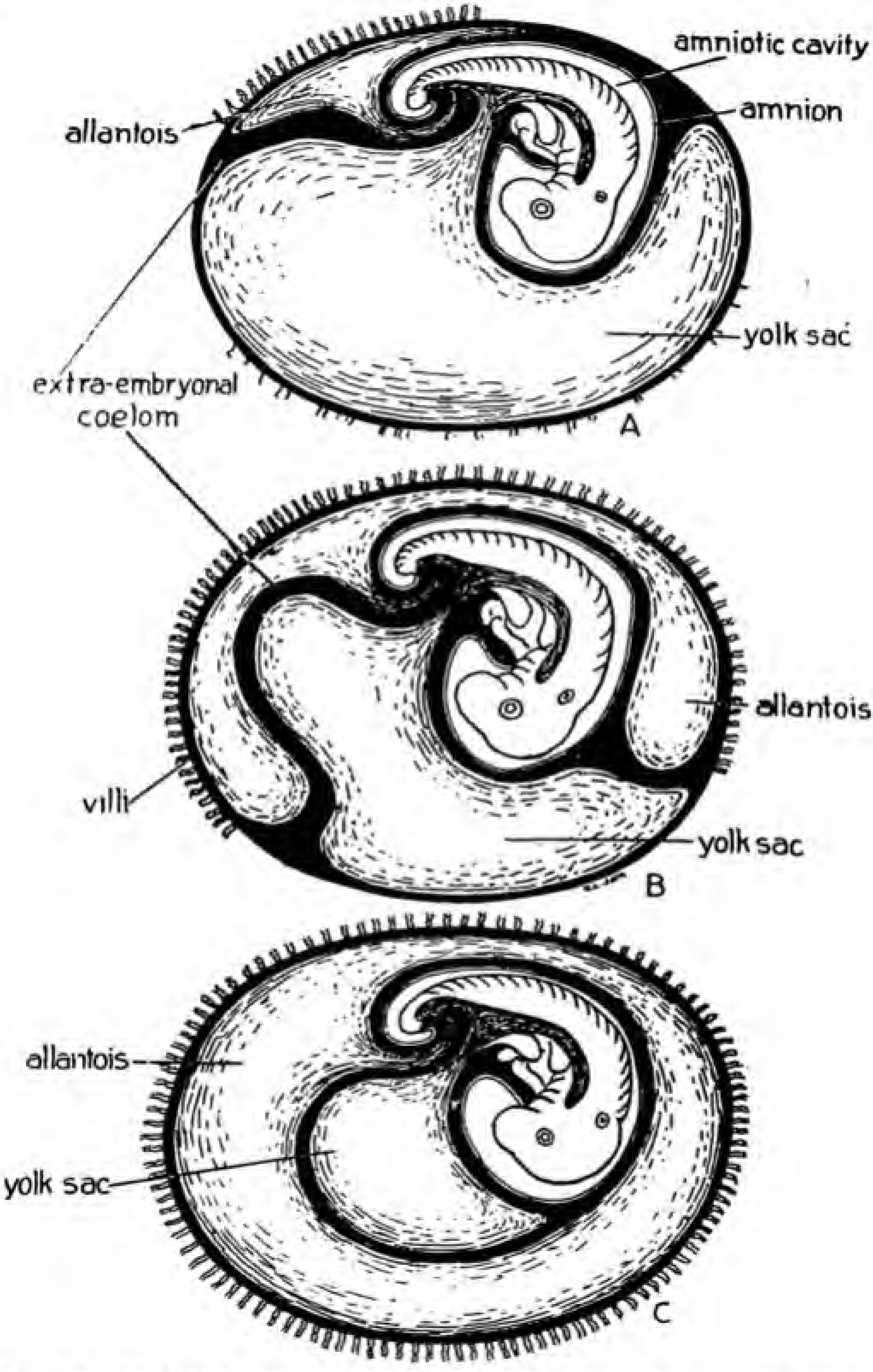


FIG. 360. Embryo of mammal with yolk sac, amnion, allontois and serosa and showing the successive stages in the formation of chorionic villi. A. Diagram showing the large yolk sac and the allantois pushing into the extra-embryonal coelom B. The allantois has greatly enlarged and extended over the embryo, at the same time becoming closely applied to the serosa to from the chorion. The villi are appearing externally. C. The allantois has completely enclosed the embryo, the yolk sac and amnion and the chorionic villi are complete.

villi penetrate corresponding depressions in the epithelium of the uterus. The intimate connection between the foetus and the uterine tissue is called ***placenta***. The placenta comprises 1. the ***foetal placenta***, formed by the chorion and 2. the ***uterine placenta***

FIG. 361. Human embryo, 10 mm long, *in situ* within the amnion and villi covered chorion. Note the large yolk sac and the prominent tail (*Original photograph of a specimen loaned by Mr. D. S. Choudhary, Lecturer in Anatomy, Thomson Medical College, Agra*).

formed by the uterine epithelium. The foetal and uterine placentas are so intimately bound up together, that at the time of birth of the young, more or less of the uterine tissue is also torn off as ***decidua***. There is no mixing of the foetal blood with that of the mother.

The embryo has its own separate circulatory system. The blood capillaries of the foetal placenta come into intimate contact by intertwining with

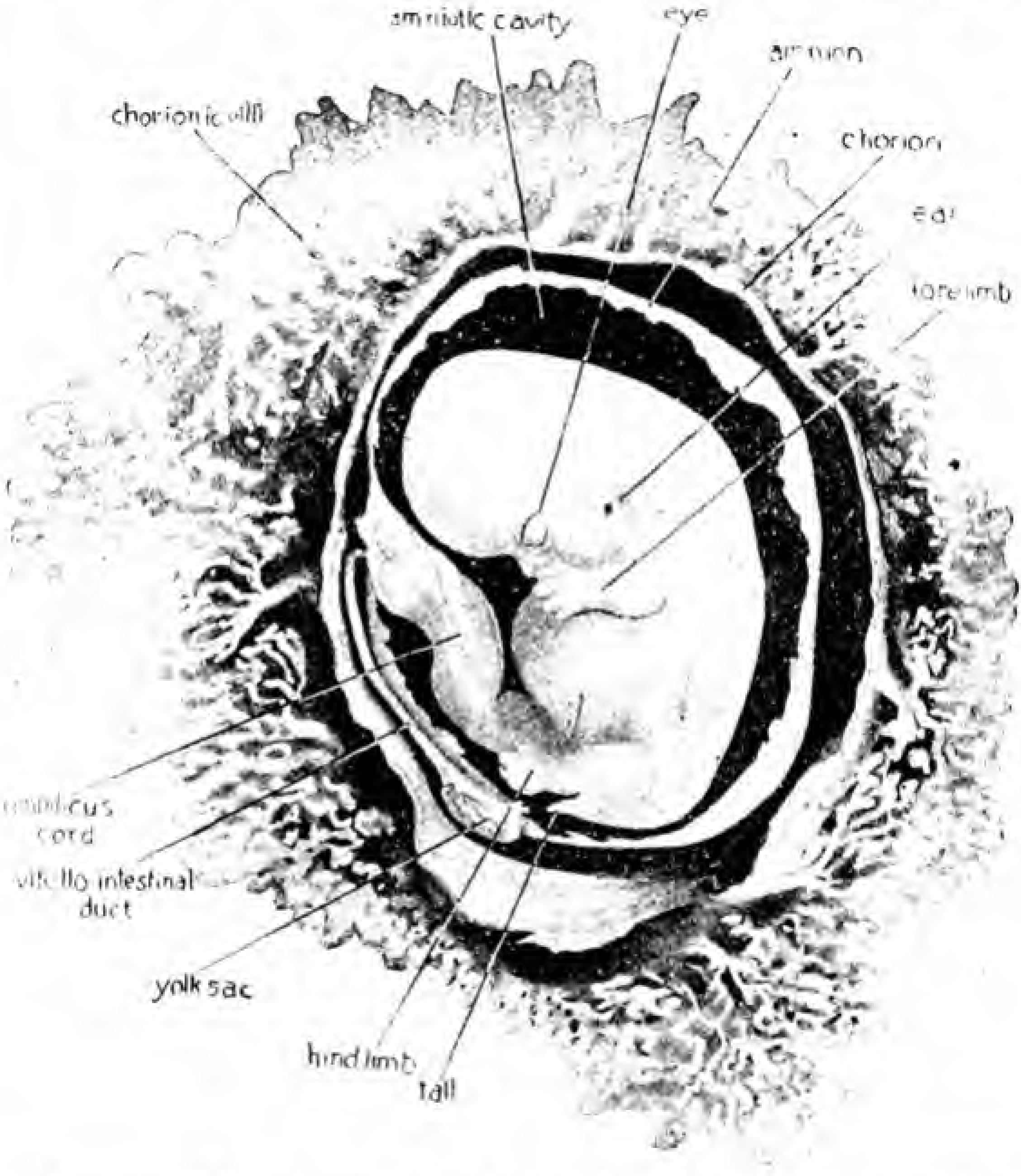


FIG. 362. Human embryo, 19 mm long, age six weeks. Note the chorion with its villi, the amnion, the vitello-intestinal duct, umbilicus cord, yolk sac and stumpy tail. (*After Kollmann from Oscar Hertwig, Die Elemente der Entwicklungslehre des Menschen u. der Wirbeltiere, Gustav Fischer*).

the capillaries of the uterine placenta. Exchange of nourishment and oxygen between the blood of the embryo and that of the mother is

facilitated. An allantoidean placentation is characteristic of only mammals.

Some mammals, like the duckbill and spiny anteater of Australia, lay eggs and have no placentation. In a few, like the kangaroo and

FIG. 363 Human embryo, [illegible] weeks old, still attached to the placenta and amnion by the umbilical cord. (Original photo of a specimen in the *Zoology museum, St. John's College, Agra.*)

opossum, the villi are few or are wholly absent. In all the rest of the mammals there is a placentation. In horse, pig, hippopotamus and camel the villi are uniformly present. In the cattle they are irregularly scattered. In cats and other carnivores the placenta is zonary. Apes, rodents and man have discoidal placenta

On the basis of the embryonic envelopes, OWEN, HUXLEY, and KOLLIKER have divided the Vertebrata as follows:

I. Anamnia. Without amnion. *Amphioxus*, Cyclostomata, Fishes and Amphibians.

II. Amniota. With yolk sac, amnion, serosa and allantois.

A. Sauropsida. Egg-laying amniotes. Reptiles and birds

B. Mammalia With the exception of the monotremates, the eggs develop within the mother.

(a) Achoria. The outer envelope lacks villi or has very few villi. Monotremates and Marsupials.

(b) Choriata. The outer envelope becomes a villous coat.

Mammalia non-deciduata

1. With the chorionic villi uniformly scattered. Perissodactyla, Suidae, Hippopotamidae, Tylopidae, Tragulidae, Cetacea, etc.

2. Placentalia. The chorion is locally transformed into placenta.

i. Semiplacenta (of Strahl) With numerous cotyledons. Ruminants.

Mammalia deciduata

ii. Placenta zonaria. Carnivores.

iii. Placenta discoidea. Apes, Rodentia, Insectivora, flying foxes, etc.

The Mammals fall into three categories according to the mode of intra-uterine nutrition of the embryo :

In the first category, to which belong only the Monotremata and the Marsupials, the embryonal envelopes are mostly as in the reptiles and birds. The chorion is smooth and lacks the villi, but being deeply imbedded in the highly vascular uterine mucosa, absorbs the necessary nourishment for the developing embryo. In the second group we find a greater perfection of the intra-uterine nutrition. The chorion becomes rich in blood capillaries and a few villi are developed. The uterine mucosa also presents finger-like depressions, into which the chorionic villi penetrate. This type is met with in the pigs, Perissodactyla, Hippopotamidae, Tylopidae, Tragulidae, Sirenia and Cetacea. In the third category the intra-uterine nutrition reaches its greatest perfection. A large number of highly branched chorionic villi penetrate in a complicated manner into corresponding depressions in the uterine mucosa. The Ruminants posses, a special type of placentation. On the chorsion are developed numerous, small, foetal placentas called cotyledons, often varying from 60 to 100 as in sheep and cow, or from only 5 to 6 as in the goat. The cotyledons fit into corresponding caruncles or depressions in the uterine tissue The placenta zonaria is met with in the Carnivora. The chorionic bag is barrel-shapped and with the exception of the two poles, the villi are present like a girdle in the middle. The placenta discoidea is found in Insectivora, Rodentia, flying foxes, apes and man. The part of the chorion that develops into the plecenta is here very small, but the villi are the most highly branched and most intimately intertwined with the uterine placenta. Several intermediate forms of placenta occur in various different mammals.

Classification.—

Class MAMMALIA.

Subclass I. *PROTOTHERIA* (formerly Monotremata or Ornithodelphia). Egg-laying mammals, with cloaca, no uterus, many reptile-like features, mammary glands without nipples Confined to Australia. Examples : *Tachyglossus* (formerly *Echidna*) spiny ant-eater : nocturnal, feeding on ants (Fig. 364) ; *Ornithorhynchus* duckbill with webbed toes, flat beak ; aquatic (Fig. 364).

Subclass II. *ALLOTHERIA*. Extinct mammals with multituberculate dentition.

Subclass III. *THERIA*. Marsupial and true placental mammals, with external pinna for ear ; heterodont and diphyodont ; ureters open into urinary bladder, no cloaca ; the two oviducts separate, each modified posteriorly into an uterus : mammary glands with nipples.

Infraclass i. PANTOTHERIA. Extinct mammals.

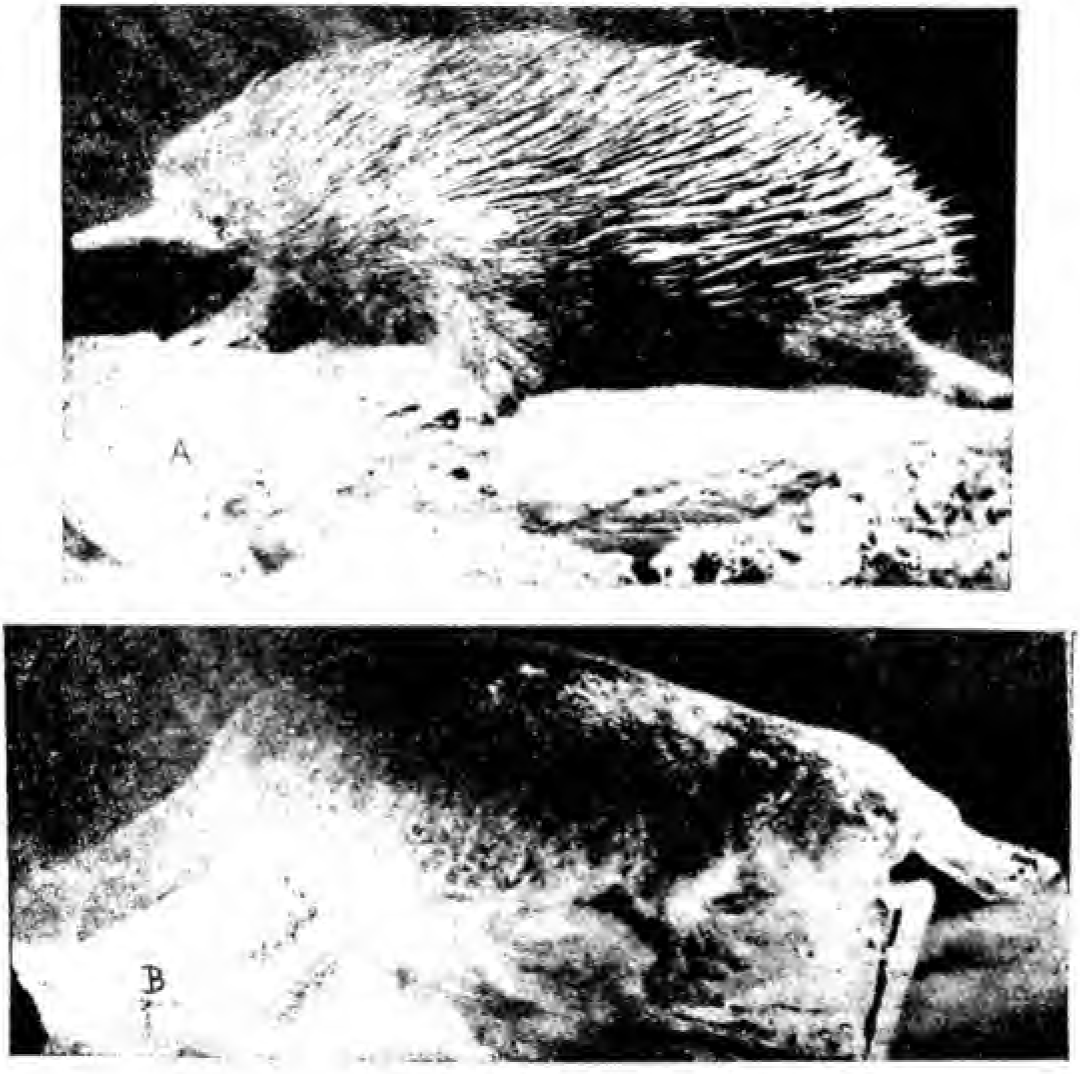


FIG. 364. Subclass Prototheria. A. *Tachyglossus* (= *Echidna*) *aculeatus*, the spiny ant-eater or the common echidna, is confined to Australia. It has a short, straight beak as an adaptation for feeding on ants. It is a powerful digger. B. *Ornithorhynchus anatinus*, the duckbill has webbed feet and is adapted for a semi-aquatic life. Its beak is broad and flat. (*Original photo of specimens in the Zoology Museum, St. John's College, Agra.*)

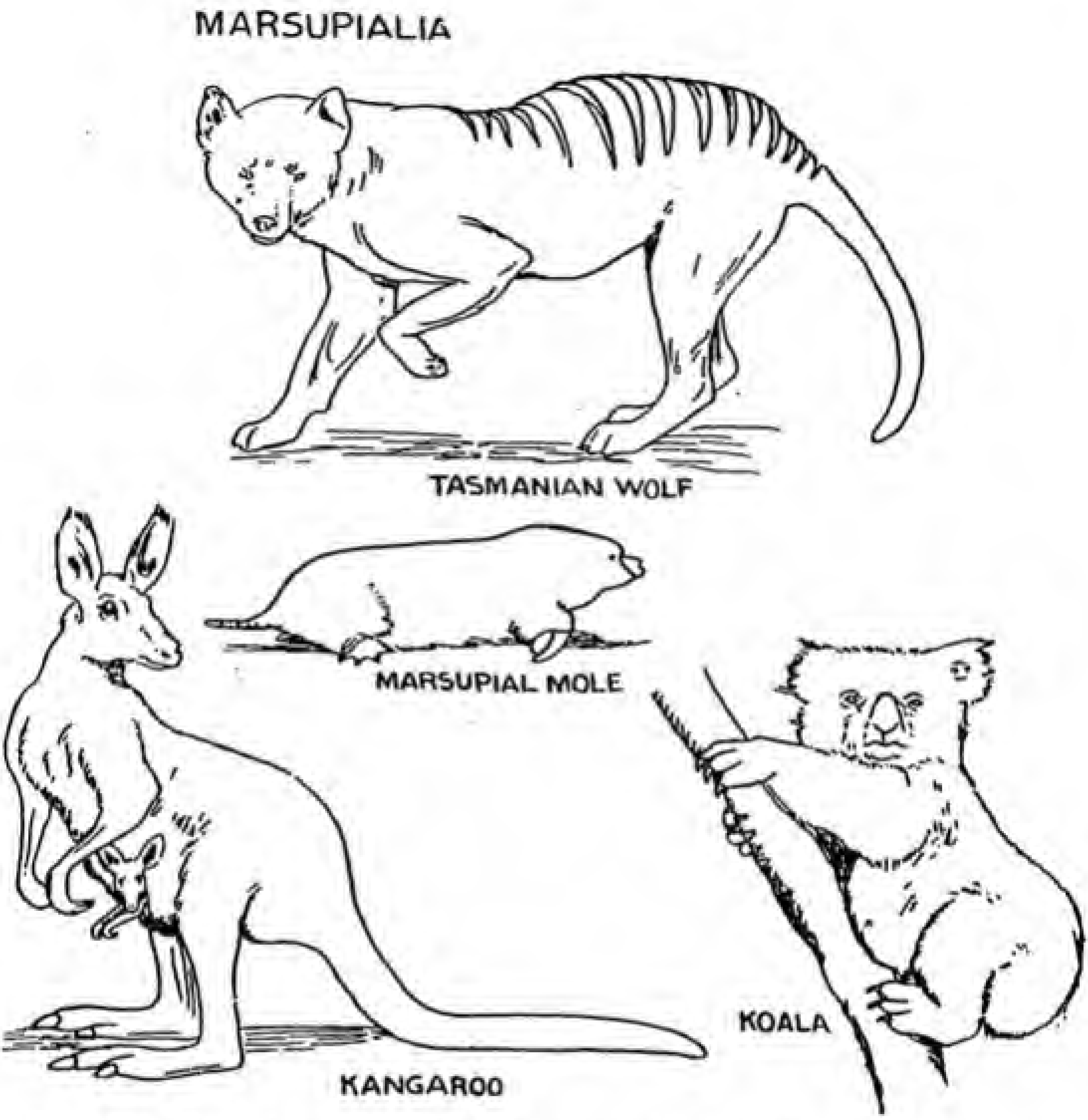


FIG. 365. Infraclass Metatheria. Marsupaial mammals are confined to the Australian region, except for the opossums that occur in America. The young are born in a very early stage of development and make their way into the pouch of the mother. Here they become fastened to the mammae. Tasmanian wolf is a dreaded carnivore. The marsupial mole is quite without eyes and eyelids and has a burrowing habit. It travels underneath the sandy surface in search of insects on which it feeds. The kangaroo is a gregarious animal that can often cover twenty feet in a single bound. It feeds on leaves and grass. Koala or "Teddy bear" is a pretty [illegible] animal that is completely arboreal. It feeds exclusively on leaves of the eucalyptus tree. Its tail is vestigial. (*By courtesy of the American Museum of Natural History.*)

FIG. 366. Infraclass Metatheria, *Didelphys* the American opossum. (*After Vogt and Specht*).

FIG. 367. Infraclass Matatheria. *Dasyurus*, the "tiger cat" of Australia. (*After Vogt and Specht*).

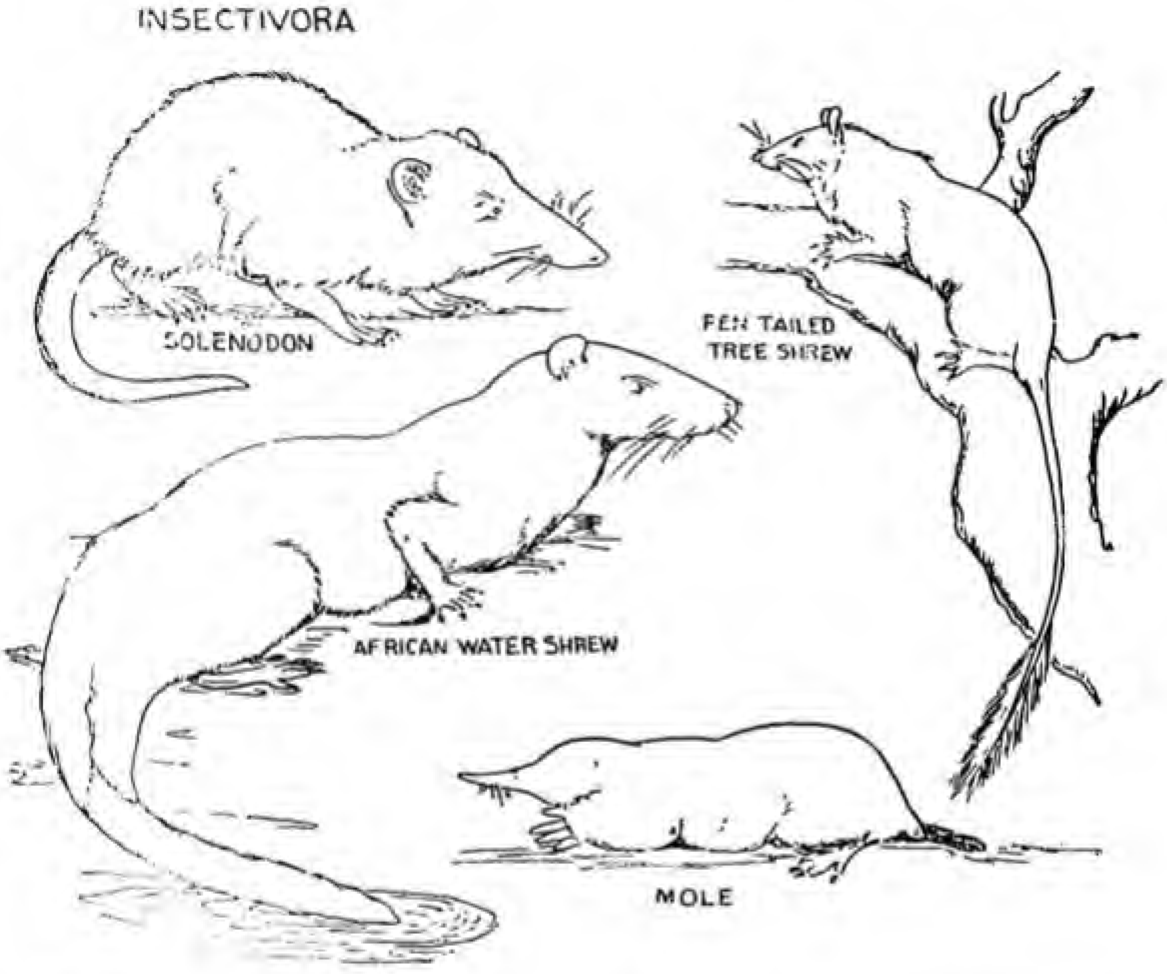


FIG. 368. Insectivores are small primitive mammals that feed on beetles, worms and snails obtained by digging underground. The muzzles are pointed to facilitate seeking out insects in holes. *Solenodon* hails from West Indies and looks like a large rat. The pen-tailed tree shrew comes from Sumatra and Borneo. Its tail is long and bears a feather-like fringe at the tip. Moles are powerful diggers; their fore limbs are stout and eminently fitted for this habit. (*By courtesy of the American Museum of Natural History*).

Infraclass ii. METATHERIA (formerly Marsupalia or Didelphia). Marsupial mammals, with pouch on belly; uterus and vagina double; the young very prematurely born and kept as "mammary foetus" in the marsupium (=pouch) and attached by the mouth to the nipples until fully developed. Examples: *Didelphis* opposums from South America (Fig. 366); *Sarcophilus* the Tasmanian devil, *Notoryctes* marsupial mole, *Perameles* bandicoot, *Phascolarctus* the teddy bear or koala and *Macropes* the kangaroo from the Australian region (Fig. 365).

Infraclass iii. EUTHERIA (formerly Placentalia or Monodelphia). True placental mammals. Single uterus and vagina; complete intra-uterine development with allantoidean placenta. No Pouch.

Order 1. I n s e c t i v o r a. Small animals with long and pointed snout, five-toed feet. Food consists of mainly beetles, grubs, worms and snails obtained by digging in the earth or by hunting on the ground The Insectivora are of unusual interest, because from them descended the Primates (apes, man, etc). Examples: *Talpa* and *Crocidura* moles, subterranean, velvety rat-like forms with enlarged palm; *Sorex* shrews mouse-like forms with normal palms; *Erinaceus* hedgehog, with spines on the back. (Fig. 368).

Order 2. D e r m o p t e r a. Large expansion of skin stretched between the legs and tail, enabling the animal to glide through the air from tree to tree like a flying squirrel. Examples: *Galeopithecus* flying lemur from S. E. Asia, taguan (Fig. 369).

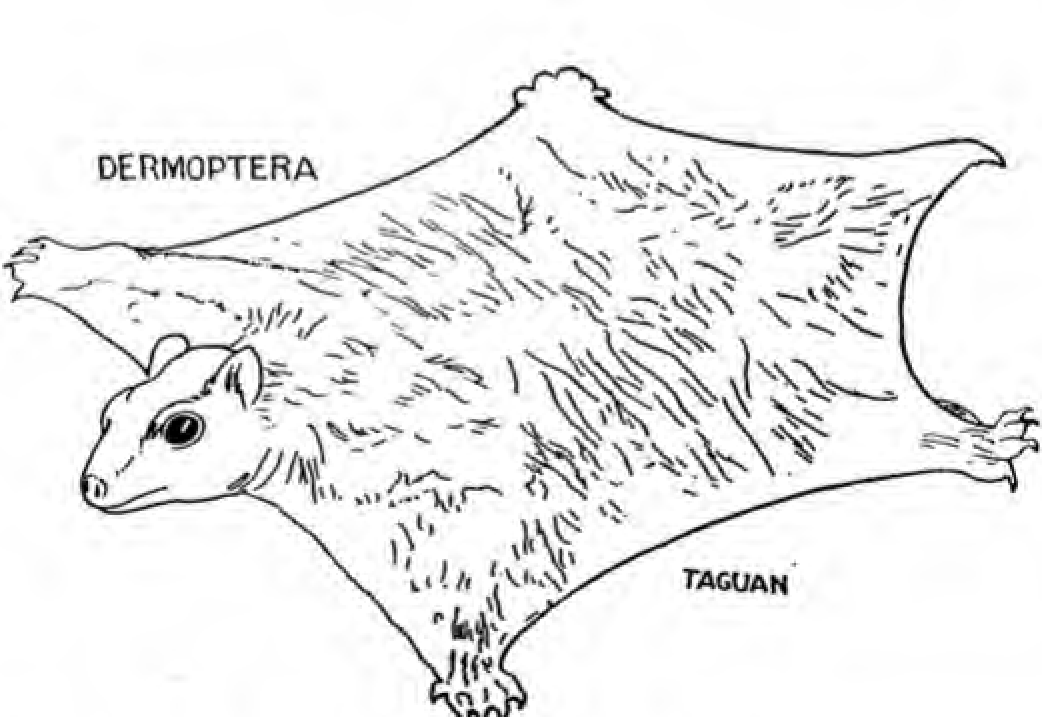


FIG. 369. The 'flying lemur' or taguan glides from tree to tree with the help of large skin folds stretched between the legs and tail. (*By courtesy of the American Museum of Natural History*).

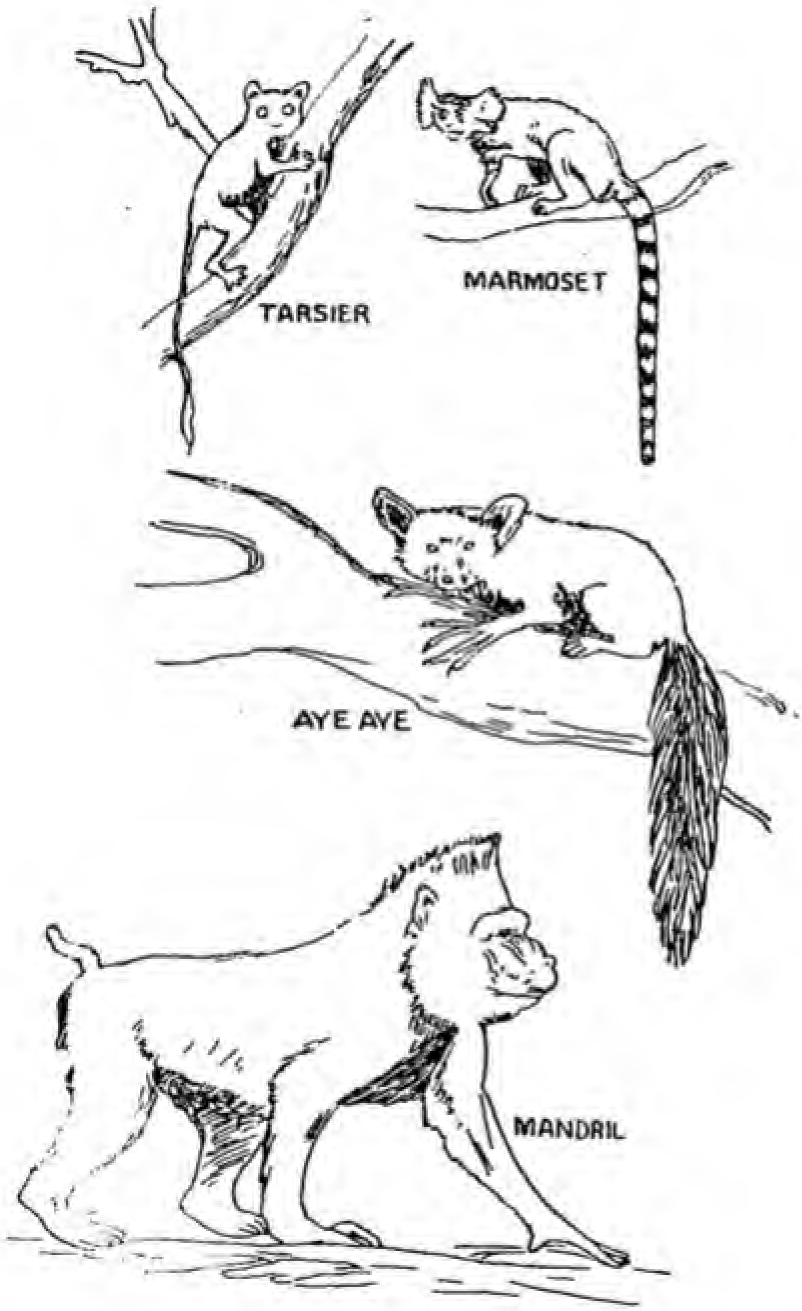


FIG. 370. Order Primates. The tariser is an aberrant Old World form. The marmoset is a New World monkey, with lateral tufts of hair on head. The aye-aye is a remarkable lemur, with rodent-like incisor, with which it tears open wood for hidden insects. The mandril or the the dog-faced monkey of West Africa is the "most colourful of all mammals." (*By courtesy of the American Museum of Natural History*).

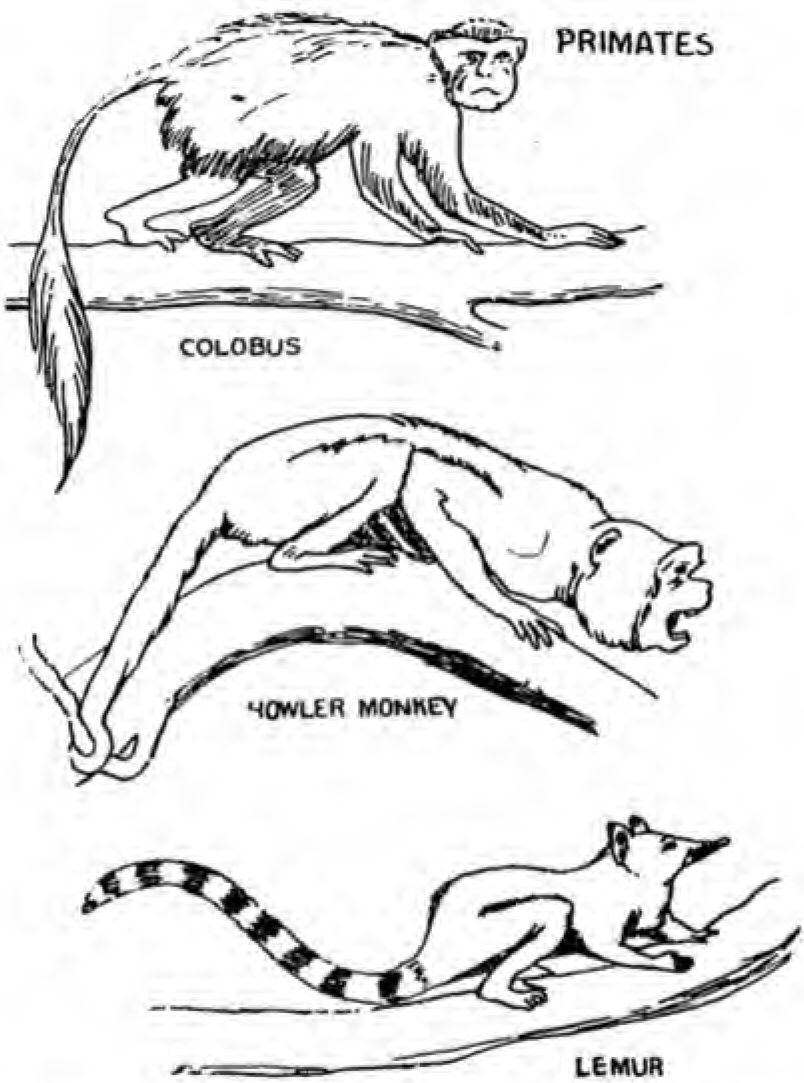


FIG. 371. Order Primates. Lemurs are confined to the Old World and predominate in Madagascar. The muzzle is usually pointed and the tail never prehensile. Pithecoidea-Platyrrhina : *Alouatta senicula* the howling monkey belongs to south America. It has an ugly face. The greatly inflated hyoid bones and the large larynx increase its voice in the male, which is audible at a distance of several miles. Pithecoidea-Catarrhina : *Colobus* is related to the Indian langurs. (*By courtesy of the American Museum of Natural History*).

Order 3. Chiroptera. Bats. The only flying mammals; fore limbs and the second to fifth fingers greatly elongated and supporting a thin membrane—the wing; hind limb short with recurved claws; nocturnal mammals that spend the day by hanging head downwards in dark caves, old buildings or trees. They range from the small insect-eating bats to the large fruit-eating "flying foxes". Some like the vampire bat of S. America, suck blood. Have very keen sense of smell and hearing. Examples: *Pteropus* the flying fox; *Vesperugo* and *Myotes* insectivorous bats.

Order 4. Primates. ("Inquisitive mammals.") Lemurs, monkeys, apes, men. Primitive mammals adapted for arboreal life—all the four limbs more or less hand-like, thumb and great toe opposable, i.e., set off at an angle to the rest, so that grasping is possible. The feet of man specialized for terrestrial existence. Orbit usually directed forwards and surrounded by a bony ring. Molars tuberculate. Nervous system highly developed as an adaptation for arboreal life, especially the centres of alertness, sight and intelligence, smell poorly developed. Food mainly of fruits and seeds, sometimes flesh also.

Suborder a. LEMUROIDEA. Most primitive of the order, with long skulls and tails, second toe with claw, others with nails. Example: *Lemur* (Figs. 371, 373) from Madagascar, Africa, S. E. Asia, and Philippines.

Suborder b. TARSIOIDEA. Most aberrant of the primates, except man; tarsi of hind leg very long; eyes very large and protruding; ears long; tail short or absent, nocturnal. Examples: *Tarsius* and *Loris* (Figs. 370, 373) from India. Can turn the head completely back so that it can look behind without turning the body. *Nycticebus* slow loris from India.

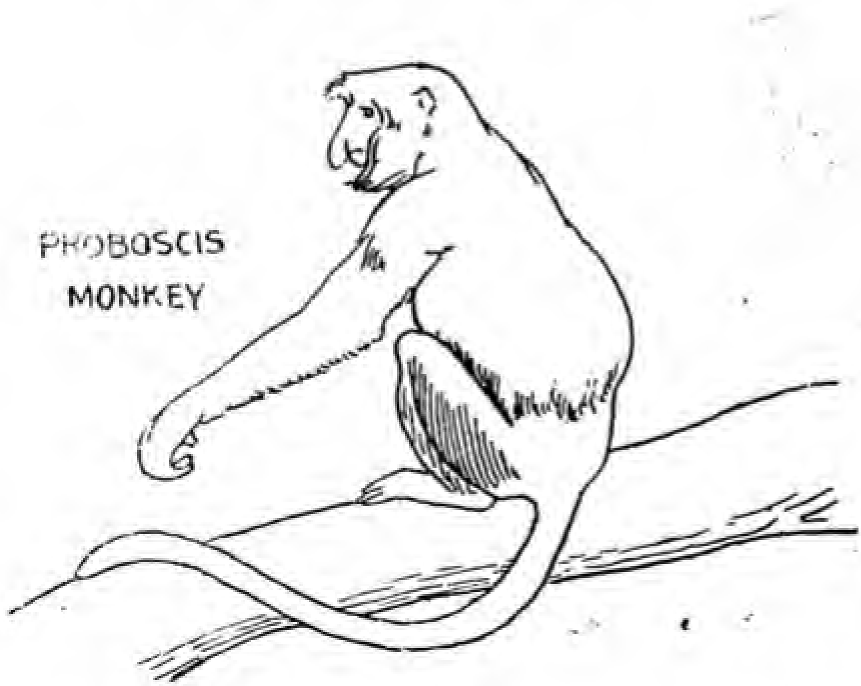
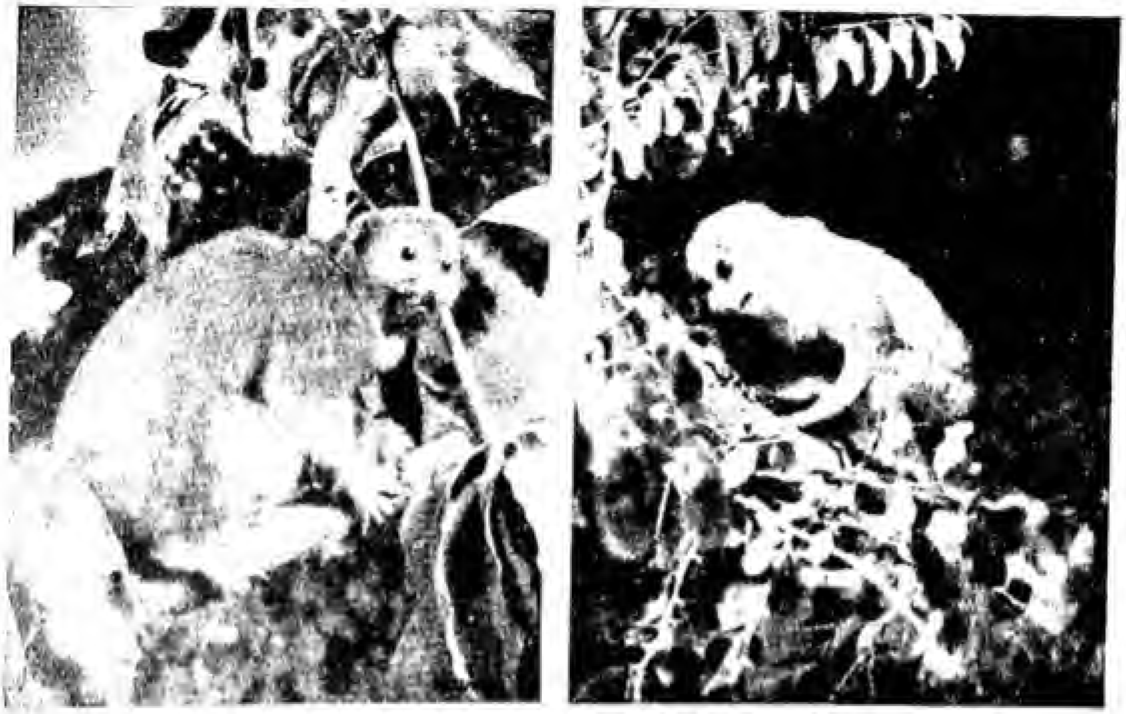


FIG. 372. Primates. Cercopithecidae. *Nasalis*, the proboscis monkey of Borneo has a long pendulous nose in the male. It feeds on leaves and has an enormous abdomen. (*By courtesy of the American Museum of Natural History*).



A B

Fig. 373. Order Primates. A. *Hapalemur simus* is completely arboreal and occurs in Madagascar. B. *Loris tardigradus* the slender loris of South India and Ceylon is an [illegible] arboreal nocturnal creature that feeds on leaves, fruits, grasshoppers, lizards, etc.

A B

Fig. 374. Order Primates. A. *Colobus guereza*, the common guereza of equatorial Africa is red-coloured and has a long tail. B. *Semnopithecus* the langur is Asiatic.

FIG. 375. Primates (Pongidae). *Ponga* the Orangutan (= man of the forest) is a large, tree-living, red haired ape from Borneo and Sumatra. (*By courtesy of the American Museum of Natural History*).

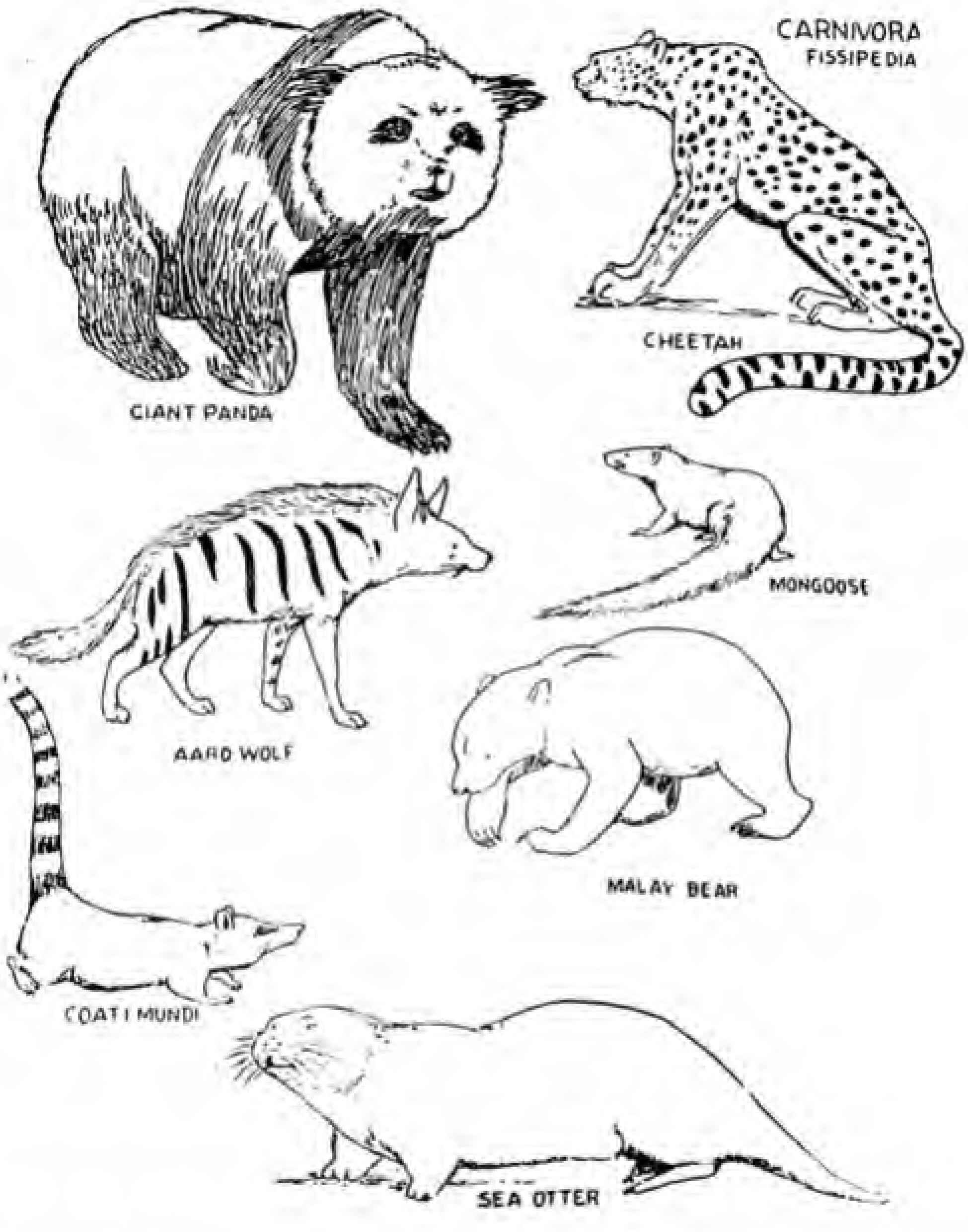


FIG. 376. Carnivora fissipedia are terrestrial flesh-eating mammals. The giant panda is the largest land carnivore. It is a rare bear-like animal that inhabits the Himalayas and feeds on bombo shoots. Cheetah or the hunting leopard of Africa and Asia is capable of great speed. It can be trained to hunt with men. The aard wolf is a relative of hyaena, occurring in Africa, where it lives on white ants. The mongoose of India is a famous snake killer. The Malay bear subsists on fruits. Sea otter, once abundant in North Pacific, yields fur, often costing $1400 each. Coati mundi occurs in tropical America. Aard wolf of Africa subsists on whiteants. (*By courtesy of the American Museum of Natural History*).

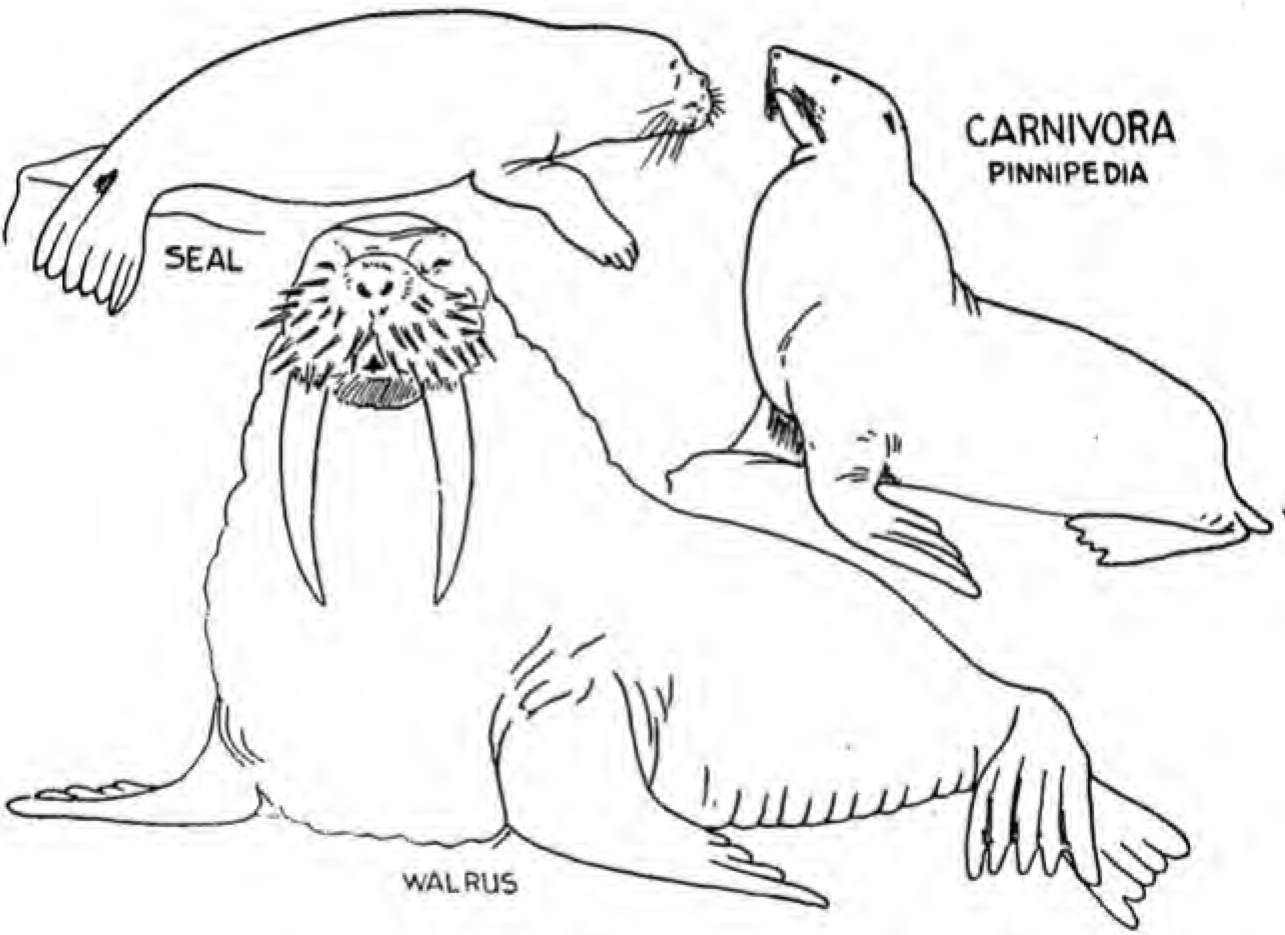


FIG. 377. Carnivora pinnipedia are aquatic flesh-eating mammals, but come to land or ice fields for basking in the Sun or for birth of the young. The seal is the most aquatic of the group. Its sharp teeth help in capturing fish but are useless in cutting up food. Seal meat and seal skin are highly prized. The sealion can walk clumsily on land. The walrus has the upper canine elongated into a tusk, used in digging up clams for food and in fighting. These are all at present confined to the arctic seas. (*By courtesy of the American Museum of Natural History*).

Suborder c. PITHECOIDEA (formerly *Anthropoidea*). Monkeys, apes and man. Digits with flattened nails; tree-inhabiting or terrestrial and diurnal; lips free from gum and protrusible to enable sucking of milk from the nipple; eyes enclosed completely behind by bone; no *rhinarium* or moist skin round the nostrils; fourth digit of hand and feet not longer than the third, which is the longest in the hand (Fig. 370).

Superfamily A. *CEBOIDEA* (formerly *Platirhinii*). New World monkeys with flat wide interval between the nostrils; no cheek pouches; three premolars on each side above and below.

Family 1. HAPALIDAE. Central and South American marmoset, with lateral tufts of hair on the head.

Family 2. CEBIDAE. Central and South American monkeys, with prehensile tail. Examples: *Ateles* spider monkey; *Cebus* capuchin monkey and *Alouatta* howler monkey (Fig. 371), the male of this monkey has an enormous bony throat pouch, giving such tremendous strength to its voice. Their calls are heard from two miles.

Superfamily B. *CERCOPITHECOIDEA* (formerly *Catarhinii*). Old World monkeys. Nostrils directed downwards, with only a narrow interspace; tail never prehensile; cheek with internal pouches; buttocks with ischial callosities; only two premolars on each side above and below. The arms and legs subequal in length.

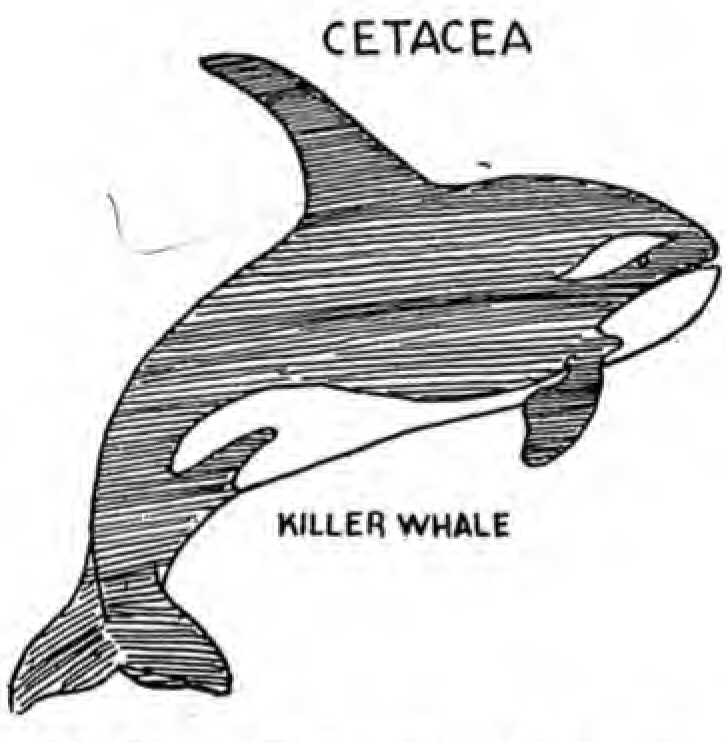


FIG 378. Order Cetacea. Whales are exclusively aquatic mammals that have lost their hind limbs. They breathe air into lungs and the "spouting" of the whale is due to the condensation of the moisture from the lungs. The young are nourished by the mother's milk. The killer whale ranges from the Arctic to the Antarctic. (*By courtesy of the American Museum of Natural History*).

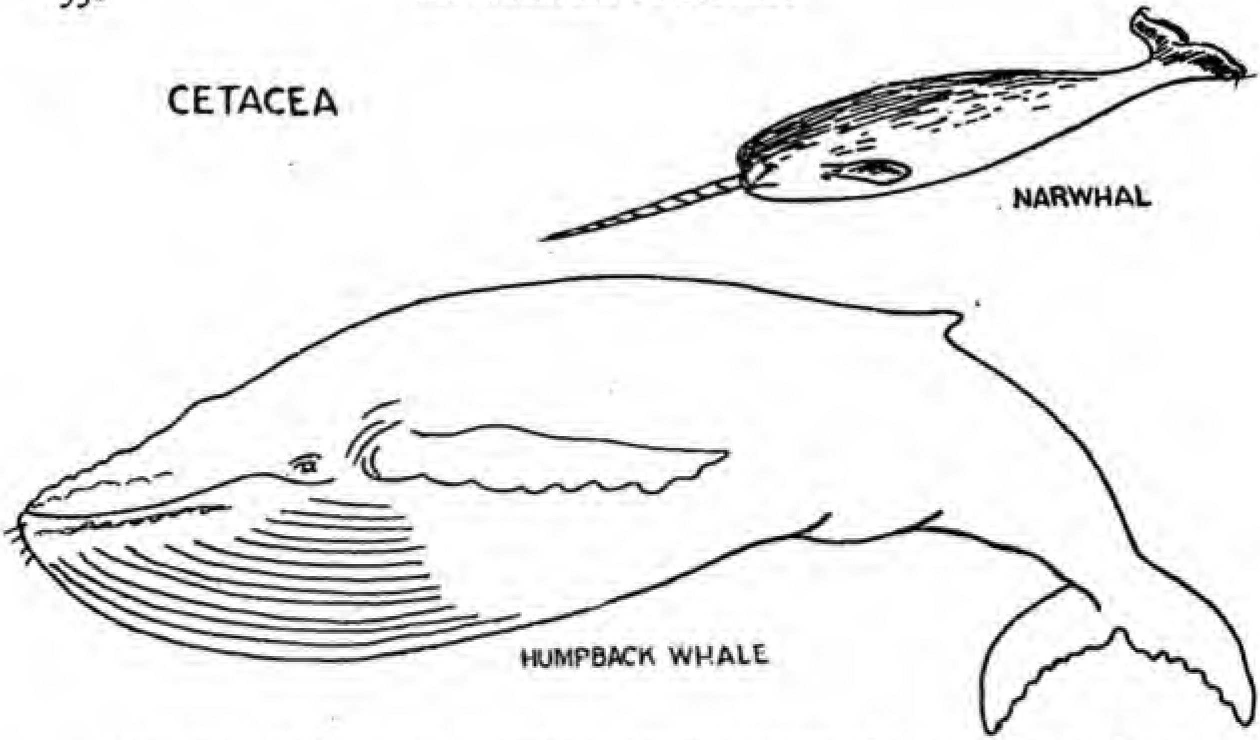


FIG. 379. The narwhal sometimes measures fifteen feet long. Its teeth are reduced to single pair of incisors. One of these, usually the left, grows into a long, spirally twisted horizontal tusk, often 9 ft. long in the male. The humpback whale is widely distributed. Its throat is marked by several plates. (*By courtesy of the American Museum of Natural History*).

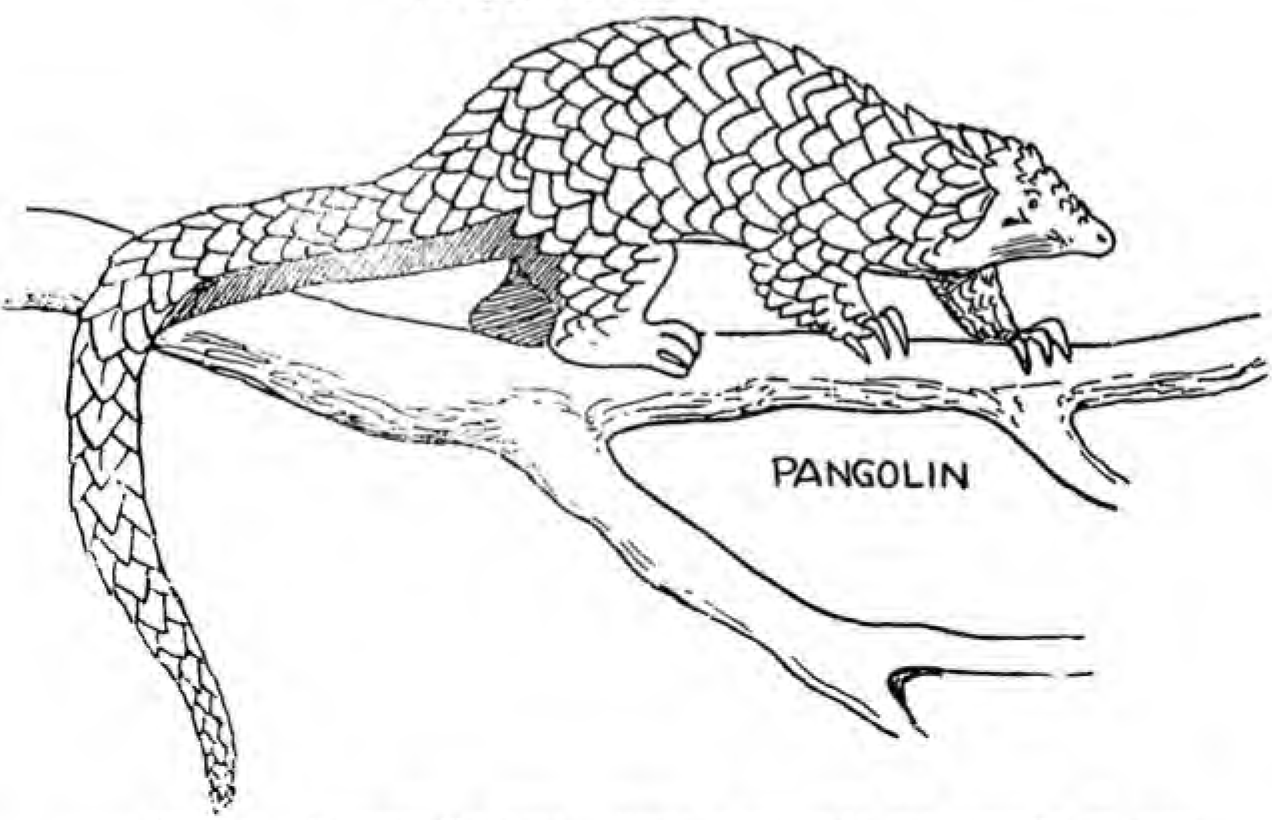


FIG. 380. Edentata-Pholidota. *Manis pentadactyla* the pangolin or scaly ant-eater from Africa and Asia (*By courtesy of the American Museum of Natural History*).

Family 1. CERCOPITHECIDAE. With cheek pouches. Examples: *Cercopithecus*, *Macaca* the common macaque monkey.

Family 2. COLOBIDAE. Without cheek pouches. *Colobus* the African black and white long-haired monkey; *Semnopithecus* the Indian langur (Fig 374); *Cynocephalus* dog-like mandrills or baboons, with short tail and of savage disposition (Fig. 370); *Nasalis* the proboscis monkey (Fig. 372).

Superfamily C. *HOMINOIDEA*. Anthropoid apes and man. Without tail and cheek pouches.

Family 1. PONGIDAE (=*Hylobatidae*). Anthropoid apes. Erect posture not perfect. Examples: *Hylobates* the gibbons (hoolock); *Siamanga* siamang of Malaya; *Pongo satyrus* the orangutan ("man of the forest") (Fig. 375) from Sumatra and Borneo, with man-like brain; beard on old males; *Gorilla* the gorilla from W. Africa, very strong, black, live in families; *Pan troglodytes* the Chimpanzee from W. Africa. More human-like than the rest.

Family 2. HOMINIDAE. Man (see Chapter XXIV).

Order 5. Edentata. Sloths (Xenarthra). Teeth reduced to molars, without enamel or sometimes no teeth. Examples: *Myrmecophagus* ant-eaters of tropical America, with elongate head and snout, slender protrusible and sticky tongue, no teeth; fore feet with stout curved claws to open ant hills. The giant ant-eater of America (Fig. 381) often five feet long. Food ants and termites. *Bradypus* sloths (Figs. 381, 382), arboreal hang back downward from branches; the thick pelage harbours algae, that make the animal look green. *Dasypus* armadillo (Fig. 381) from America; horny protective shell over bony plates in the skin of the back. *Manis* the pangolin (Fig. 380) or scaly ant-eater from Africa and Asia.

Order 6. Rodentia (formerly *Rodentia simplicidentata*). Gnawing animals. Dentition adapted for gnawing. Incisor 2/1 or 1/1 and exposed, chisel-like, rootless and growing from persistent pulp; diastema due to absence of canine; limbs with five toes ending in claws; widely distributed; food chiefly seeds, nuts, fruits, roots, stems, insects and worms.

Suborder 1. SCIUROMORPHA. Squirrel-like forms.

Family i. SCUIRIDAE. Squirrels. Diurnal rodents, with incisors 1/1, feeding on seeds and nuts. Example: *Scuirus palmarum* the common squirrel.

Family ii. CASTORIDAE. Beavers. North American rodents, with flat, oval and scaly tail; build dams and ponds to float logs cut from trees for food; nest-opening under water (Fig. 383).

Suborder 2. HYSTRICOMORPHA. Porcupines.

Family iii. ERETHIZONTIDAE. Porcupines. Body covered with long, slender, pointed quills (modified hairs). Example: *Erethizon* porcupine. Other examples: guinea-pigs, capybara (largest of all rodents).

Suborder 3. MUROIDEA. Rats.

Family i. MURIDAE. The most wide-spread of the rodents. Best known species include the house rats and mice.

Order 7. Lagomorpha (formerly *Rodentia Duplicidentata*). Hares and rabbits. Incisors 2/1, the second upper incisor smaller and behind the first; molars without roots; tail usually short or absent.

Family 1. LEPORIDAE. Hind legs elongate and adapted for jumping; ear long; tail short. Food: leaves and stems. Example: *Lepus ruficaudatus* the common Indian hare (Fig. 3-4).

Family 2. LAGOMIDAE. Ear short; no tail. Example: *Lagomys* mouse-hare.

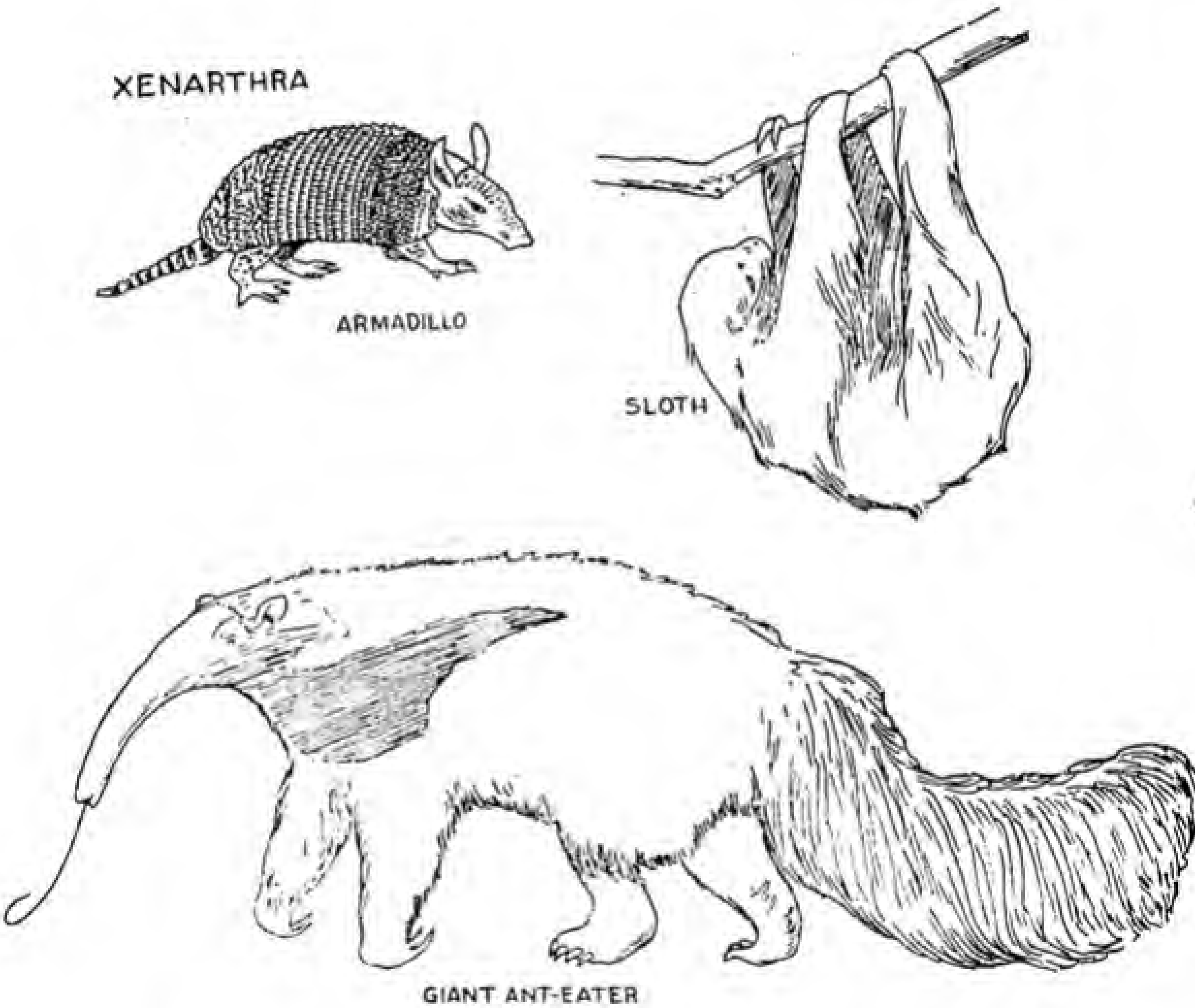


FIG. 381. American Edentates. Though called Edentates, only the ant-eater is toothless; the armadillo and sloth have reduced dentition. (*By courtesy of American Museum of Natural History.*)

FIG. 382. Edentata. The three-toed sloth is an inhabitant of America The sloth is completely arboreal and habitually hangs back downward. The feet and claws are modified into hooks The long coarse fur harbours green algae.

FIG. 383. Beaver (*Castor*) belongs to the family Castoridae and occurs in North America. Formerly it was common in Europe and North America. It has taken to water. It builds dams and ponds to float logs out for food. Aard vark from South Africa feeds exclusively on termites, which it digs out with its powerful forelegs. (*By courtesy of the American Museum of Natural History*).

Fig. 381. Order Lagomorpha.

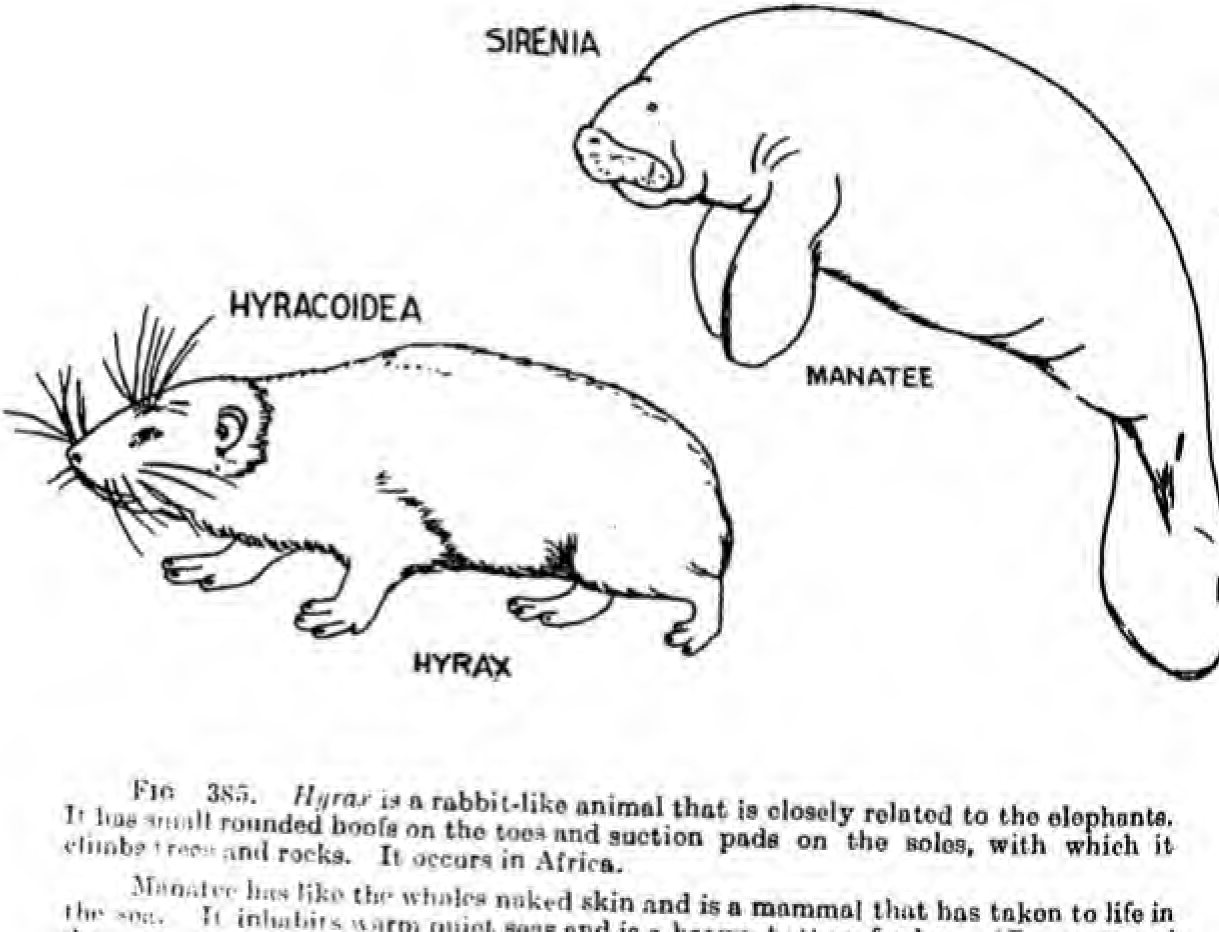


FIG. 385. *Hyrax* is a rabbit-like animal that is closely related to the elephants. It has small rounded hoofs on the toes and suction pads on the soles, with which it climbs trees and rocks. It occurs in Africa.

Manatee has like the whales naked skin and is a mammal that has taken to life in the sea. It inhabits warm quiet seas and is a heavy, bottom feeder. (*By courtesy of the* [illegible] *Museum of Natural History*).

Order 8. Carnivora. Carnivores. Flesh-eating mammals. Dentition I 3/3, C 1/1. One of the grinders modified as "carnassial" tooth for tearing flesh. Uterus bicornuate; placenta zonary. Limbs with 5 (never less than 4) digits all ending in claws. Rhinarium or moist skin area round nostrils.

Suborder I. FISSIPEDIA. Toes separate; terrestrial (Fig. 376).

Family i. FELIDAE. Dentition reduced and specialized. I 3/3, C 1/1, PM 3-2/2, M 1/1; no vibrissal hairs between nostrils. Feet with three-lobed cushion-like pads; hind feet with four toes. Examples: *Panthera* (= *Felis*) *tigris* the Bengal tiger; *Panthera leo* the lion; *Panthera pardus* the leopard; *Lynx* the lynx; *Acinonyx jubatus* the cheeta; *Felis domestica* the house cat; *Felis cougar* the American puma; *Felis chaus* the jungle cat.

Family ii. VIVERIDAE. Hind feet with five toes; internasal tuft of vibrissae present; muzzle long; dentition I 3/3, C 1/1, PM 4/4, M 2/2 = 0. Examples: *Vivera zibetha* the Indian civet, with cent glands at least in the female and opening into special pouches; *Herpestes mungo* the common mongoose.

Family iii. HYAENIDAE. Toes only 4 on fore and hind feet; dentition I 6/6, C 1/1, PM 4/3 and M 1/1. Example: *Hyaena striata* the Indian striped hyaena.

Family iv. MUSTELIDAE. Fur bearers. Examples: *Putorius* the stoat and weasel; *Helictis* the badger; otter.

Family v. CANIDAE. *Canis lupus* the wolf; *Canis aureus* the jackal; *Cyon* wild dog; *Vulpes* the fox; domestic dogs.

Family vi. URSIDAE. Bears with massive body, rudimentary tail and shaggy fur. Omnivorous. *Thalarctos* the polar bear; *Ursus* the grizzly bear; *Ursus arcus* the brown bear.

Suborder II. PINNIPEDIA. Aquatic carnivores with the body spindle-shaped; limbs modified into flippers or paddles for swimming. Examples: seals sea-lions walruses (Fig. 377).

Order 9. Cetacea. Whales, dolphins and porpoises (Figs. 378, 379). Exclusively aquatic; limbs completely lost; breathe air into lungs; the largest animals that ever lived.

Suborder I. MYSTACOCOETI. Without teeth but with "baleen"; breathing orifice double. Example: fin whale.

Suborder II. Odontocoeti. Teeth present throughout life; no baleen; breathing orifice single. Examples: *Delphina* the dolphin; *Orcinus* the killer whale; *Phocaena* the porpoise.

Order 10. Tubulidentata. Aard vark (Dutch meaning "earth pig"), feed exclusively on termites, which they dig out by their powerful front legs; teeth simple cylinders of dentine, traversed by numerous passages; no incisors or canines; snout long; mouth tubular; nocturnal; natural enemies: lion. Example: *Orycteropus* the African Aard vark (Fig. 383).

Order 11. Proboscidia. Elephant. Massive and spectacular mammals, with large head and flat ears; short neck; huge pillar-like legs; thick and sparsely hairy skin; long humerus and femur, short and well developed radius, ulna, tibia and fibula; feet broad and five-toed; dentition remarkable, no anterior teeth other than the upper tusks (elongated incisors), each molar tooth with many transverse rows of enamel on the exposed grinding surface, only one (or two) tooth functional at a time on each side of jaw; nose and upper lip a long flexible muscular proboscis, containing the nasal passages; gregarious animals that live in forests in herds of ten to hundred; food: leaves, bamboos, grass. Uterine gestation about 20 months, young when born 3 feet long. Only two living but many extinct species.

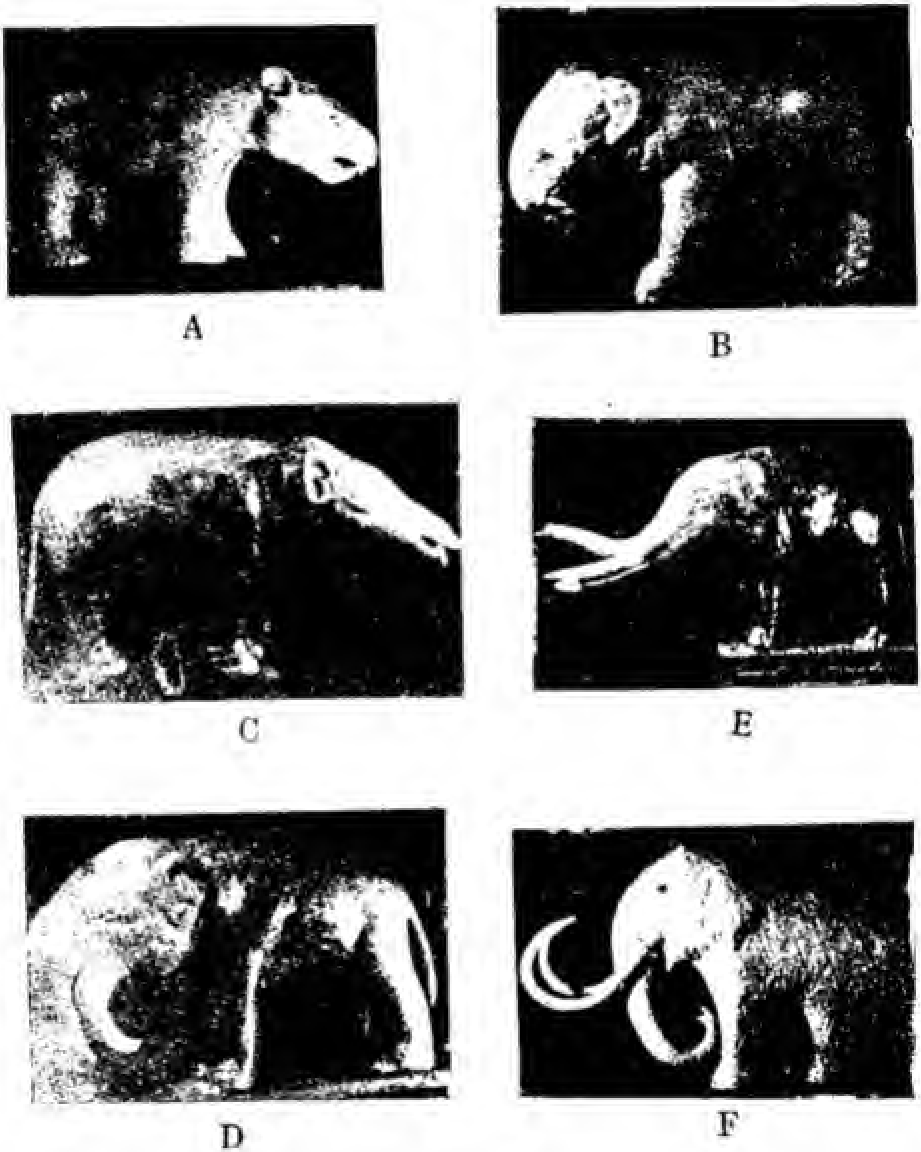
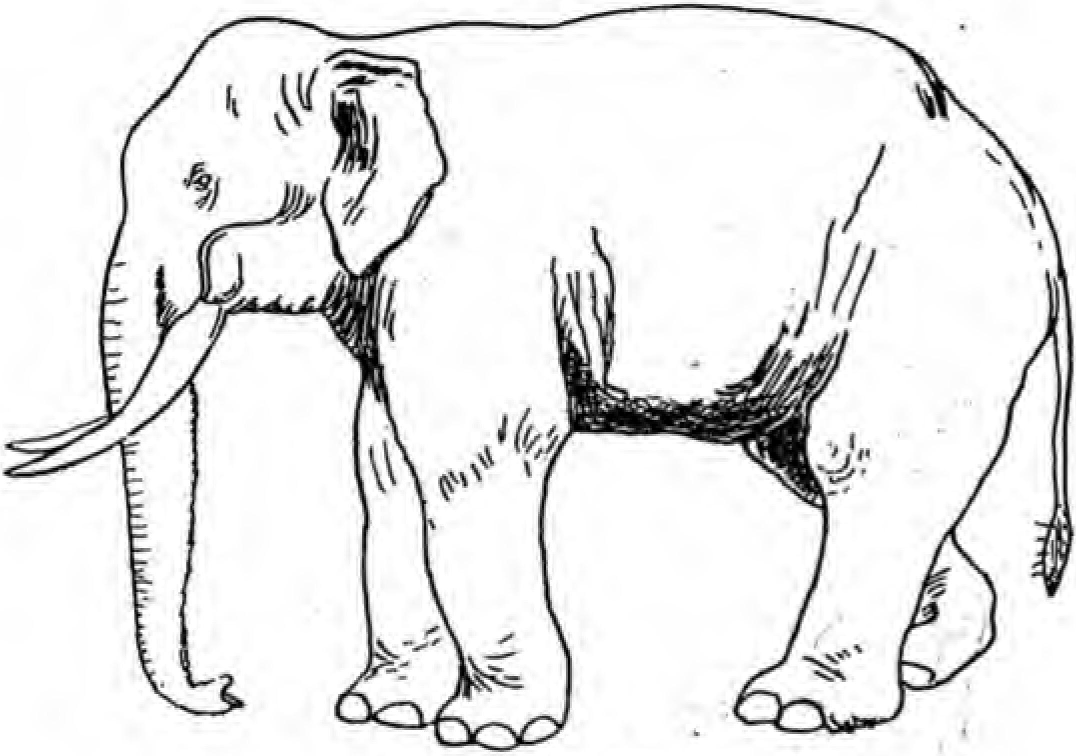


Fig. 286. Extinct Proboscidia. A, B. *Moeritherium* 2 ft. high. Fed on roots and bulbs. Dentition complete. C. *Palaeomastodon* 4½ ft., upper lip prolonged to the end of lower jaw, first incisors absent, second upper and lower incisors elongated. D. *Dinotherium* a giant primitive proboscidian. E. *Trilophodon giganteus*, a mastodon 8 ft. with [illegible] formed into 2 trunks; jaws long. F. *Elephas imperialis* the woolly mammoth 13 ft. Greatest of all elephants. It became extinct about a quarter of a million year ago. (*Original photographs of plaster models of reconstructions in a wall case in the Zoology Museum, St. John's College, Agra*).

PROBOSCIDEA



INDIAN ELEPHANT

Fig. 387. *Elephas indicus*, the Indian elephant. About a quarter of a million year ago there were no less than 20 species of elephants, of these only the Indian elephant and the African elephant now survive. They are the largest of living land mammals. They use their trunk as a hand, pick up articles, raise water, dust or fan themselves. *(By courtesy of the American Museum of Natural History)*.

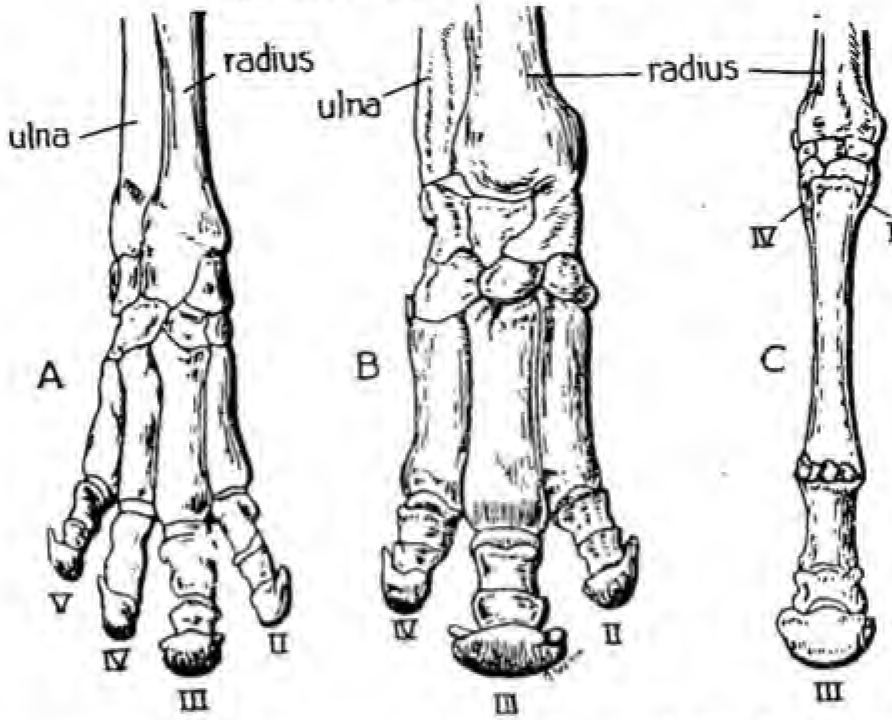


FIG. 388. Order Perissodactyla. The skeleton of the foreleg of odd-toed ungulates. A. Tapir. B. Rhinoceros. C Horse. The foot of the horse corresponds to the middle toe III. (*After Flower from Richard Hertwig, Lehrbuch der Zoologie, Gustav Fischer*).

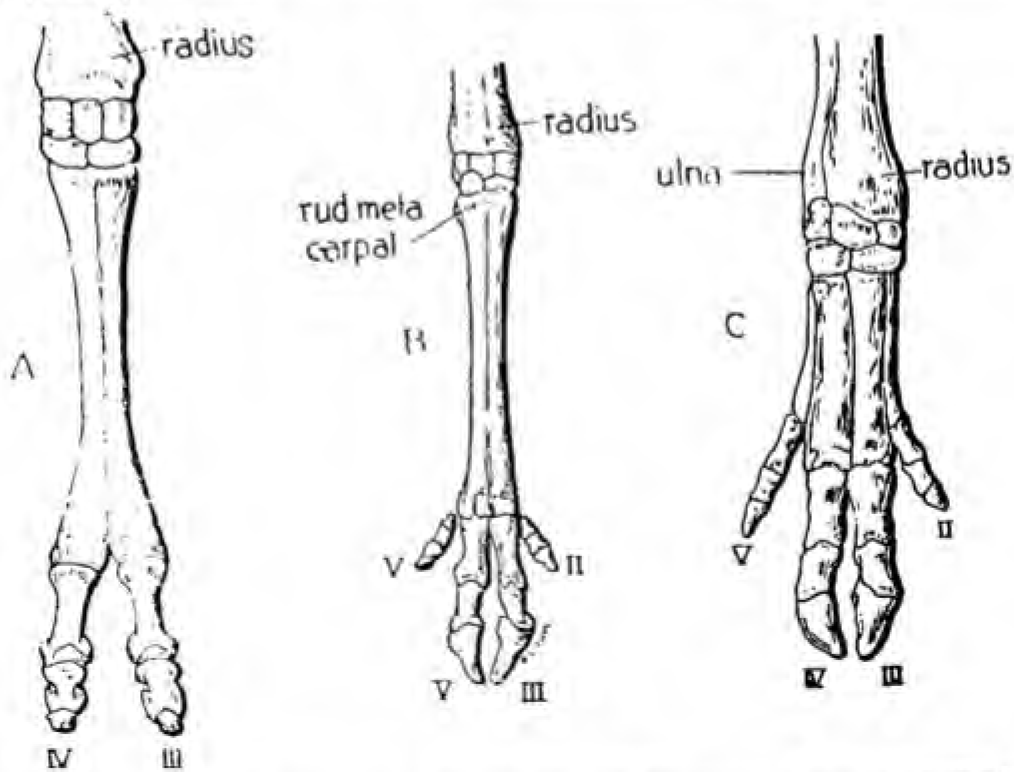


FIG. 389. Order Artiodactyla. The skeleton of the foreleg of even-toed ungulates. A. Camel. B. Deer. C. Pig (*After Flower from Richard Hertwig, Lehrbuch der Zoologie, Gustav Fischer*)

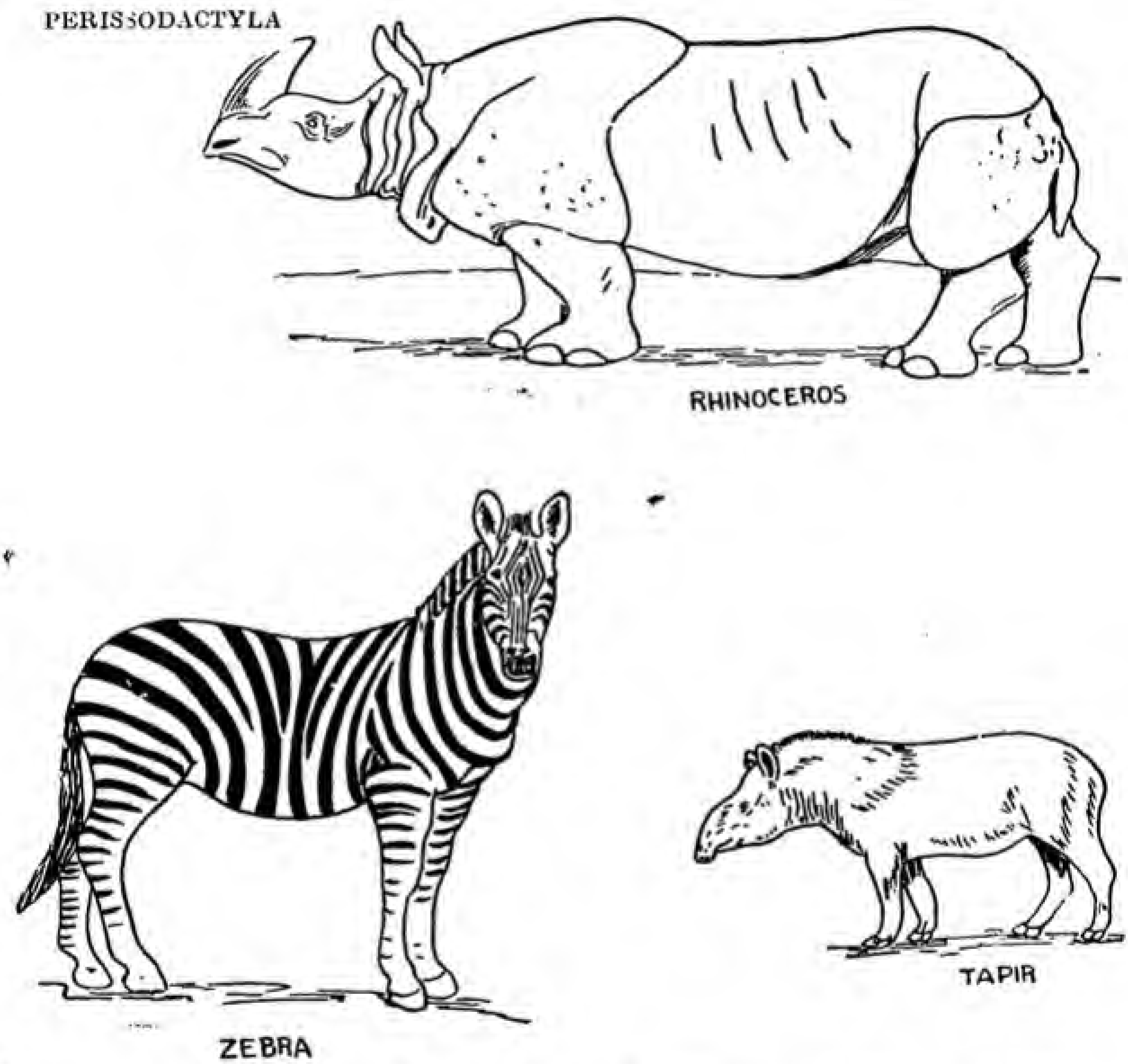


FIG. 390. The horns of the rhinoceros are composed of horny fibres from the skin. *Rhinoceros unicornis* the Indian rhinoceros occurs in Nepal, Assam and Terai. The zebra occurs in South-west Africa and is remarkable for its transverse striping. Tapirs occur in Malaya and South and Central America. (*By courtesy of the American Museum of Natural History*).

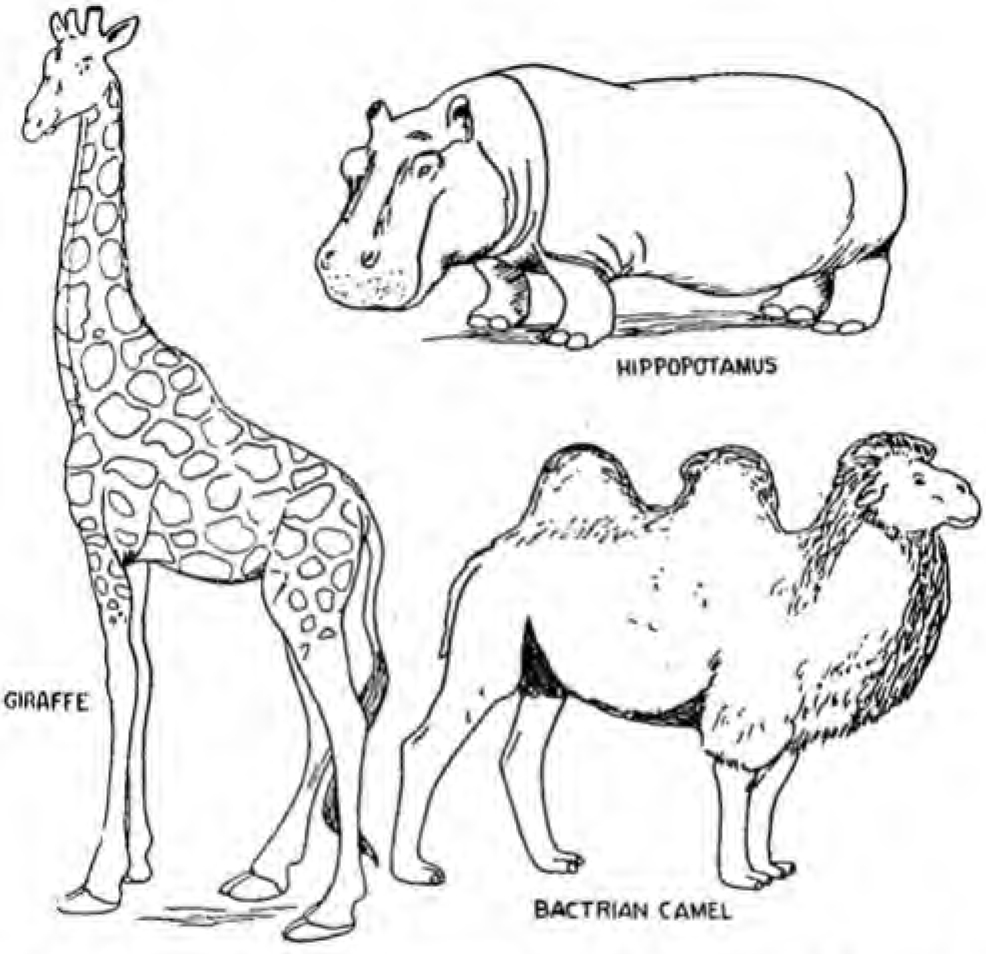


FIG. 391. Artiodactyla. *Hippopotamus* occurs in large rivers in Africa, south of Sahara. It often measures 14 ft. long. The giraffes are also restricted to Africa south of Sahara and often attain a height of 18 ft. They have skin-covered horns. The bactrian camel is two-humped and occurs in Gobi desert of Central Asia. (*By courtesy of the American Museum of Natural History*).

Suborder I. MOERITHERIUM. (Fig. 386) like a jack-rabbit, that lived in Egypt; ancestor of the proboscidia.

Suborder II. DINOTHERIOIDEA. Extinct *Dinotherium* (Fig. 386) without upper tusks but with curved lower tusks.

Suborder III. ELEPHANTOIDEA. Mastodons and elephants.

Family 1. MASTODONTIDAE. Mastodons. Teeth low-crowned; all molars present, tusks lower and upper. Example: *Palaeomastodon* mastodon (Fig. 386).

Family 2. ELEPHANTIDAE. Mammoths and elephants. Tusks only upper. Molars with high cement-covered crown. *Elephas imperialis* the extinct imperial mammoth (Fig. 386), *Elephas indicus* the Indian elephant (Fig. 387), *Loxadontia africana* the African elephant; *Mammuthus primigenius* the extinct woolly mammoth.

Order 12. H y r a c o i d e a. Coneys, Guineapig-like forms, with 4 digits on the fore limb and 3 on the hind limb; short ear and tail; dentition I 1/2, C 0/0. Example: *Hyrax*. (Fig. 385).

Order 13. S i r e n i a. Sea-cows, dugongs and mantees. Naked skinned, aquatic mammals, with the hind limbs lost; fore limbs modified into paddles; tail with horizontal fleshy paddles: no external ear. Examples: *Trcihechus* (Manatus) the manatee (Fig. 385); *Rhytina* the sea-cow; *Halicora* the dugong.

Order 14. P e r i s s o d a c t y l a. Odd-toed ungulates (hoofed mammals). Herbivorous mammals with odd number of toes, each sheathed in a horny hoof; simple stomach; the axis of the foot passes through the third digit (Fig. 388). Examples: *Equus caballus* the horse, *E. assinus* the ass and *E. zebra* the zebra, with only the third digit on the legs; *Tapirus* the tapir with four toes on the fore feet and three on the hind feet; *Rhinoceros* the rhinoceros with three toes on each foot. (Fig. 390).

Order 15. A r t i o d a c t y l a. Even-toed ungulates. Legs with two (rarely 4) functional toes, the main axis of the foot passes between the third and fourth digits (Fig. 389); many with horns; dentition generally reduced; stomach with four chambers; many ruminate or " chew the cud ".

Suborder 1. BUNODONTIDAE. No horns; teeth 38 to 44; canines enlarged as tusks. Examples: *Sus* the pig, *Hippopotamus* the hippopotamus (Fig. 391) " horse of the river ".

Suborder 2. RUMINANTIA. Teeth 32, canines small or none. Examples: *Camelus* the camel with soft broad feet (no hoof), *Auchenia* the alpaca and llama of S. America; *Cervus* the deer; *Giraffa* the giraffe; *Ovis* the sheep; *Bison* the American bison; *Bos* the oxen; buffalo; *Capra* the goat. (Figs. 391, 392).

Relation to man.—Many mammals provide food, clothing and other necessities for man. The Eskimos, for example, are almost wholly dependent upon the seal for food, clothing, oil for lamps and various other necessities. A number of mammals furnish milk. Their skins supply leather. The hairs constitute the wool. Whales provide the fat that is manufactured into whale oil, candles, etc. Ivory is obtained from elephants.

Horse, ass, cattle, sheep, goat, pig, camel, etc. are some of the mammals that have been domesticated by man since time immemorial. Most of these animals were domesticated in Asia. A number of the domesticated forms also serve as beasts of burden and for transport.

The Indian elephant is extensively used in the timber industry. The dog is perhaps the only animal that man ever befriended in Nature. Dogs are not only faithful companions, but are also extremely useful in hunting.

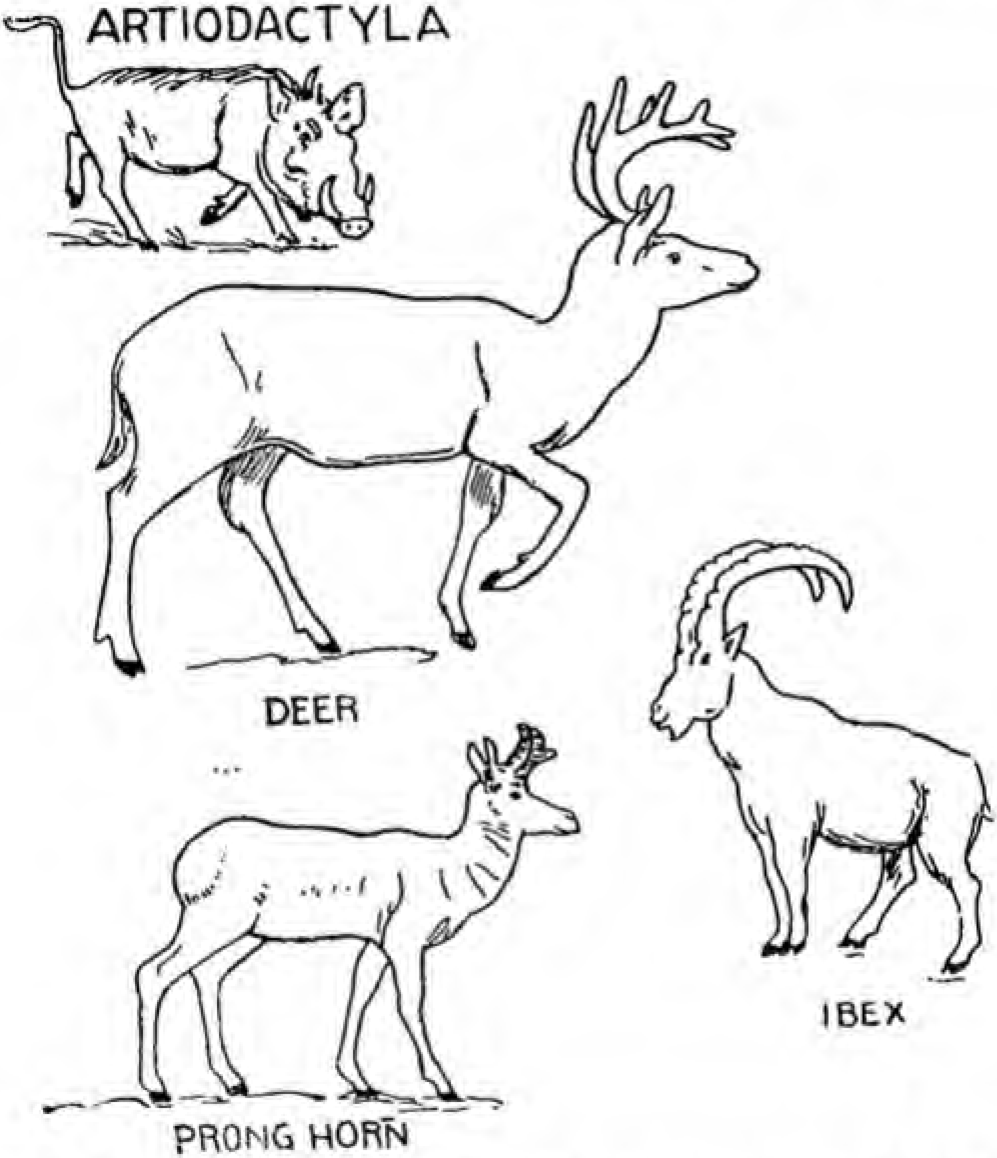


FIG. 392. Even-toed ungulates. Hogs and pigs are omnivorous Deers develop bony antlers that are shed annually. The American pronghorn is the only animal with branched hollow horns that are periodically shed The ibex belongs with sheep and goats to the genus *Capra*. (*By courtesy of the American Museum of Natural History*)

Some mammals especially the carnivores, frequently do considerable harm by killing man and his domestic animals. Others like wild pig, elephants, etc. destroy his crop. A few like the rat, the rabid dog or jackal play the role of store houses for human diseases like plague, hydrophobia, etc.

Resumé

1. Mammals possess a hairy covering on the body. They suckle their young with milk secreted by the mammary glands.
2. The skin is rich in glands Dentition is heterodont and thecodont.
3. Heart is completely four-chambered and only the left aortic arch is present. The erythrocytes are non-nucleated, biconcave, circular discs.
4. The urinary bladder and genital ducts do not open into the rectum but have independent exits.
5. Development is intra-uterine. An allantoidean placentation ensures material exchange between the foetus and the mother.
6. The Mammalia are divided into Prototheria, Allotheria and Theria. The Prototheria are reptile-like in many respects and lay eggs. Allotheria comprise extinct mammals with multituberculate dentition. The Theria include all the placental mammals.
7. Mammals are economically an important group. Many provide food, clothing, oil, tools, medicines and numerous other useful products. Several have been domesticated. The dog is a friend of man. A few mammals destroy life and crops.

CHAPTER XXIII

RABBIT AS A TYPE OF MAMMAL

Bionomics.—The RABBIT is a lovely, inoffensive and timid animal that lives in underground burrows. It comes out of its burrow at dusk to feed and meet friends. Its food is exclusively vegetarian. In the wild state the rabbit is a tawny-grey animal but the domesticated races range from white to variously coloured, long-haired rabbits to the Belgian "hares". All the domesticated races are descendents of the wild species *Oryctolagus cuniculus* (formerly *Lepus cuniculus*) of Europe. A rabbit has relatively short ears and hind limbs. It is essentially a burrowing animal. The young are blind and naked for some time. The hare on the other hand is essentially a running fellow and has longer ears that are tipped black, longer hind legs and prominent eyes. The young of the hare is clothed with hair and can see well directly after birth. The hares move about in the morning, evening and at night. There are several species of hares in India: *L. ruficaudatus* is the common Indian hare. It inhabits dry waste lands, full of bush and grass.

Rabbits live for about eight years. They commence breeding when only six months old and there are generally four litters annually. Each litter contains five to eight young. In captivity, the rabbits do not breed very successfully, due to high mortality of the young.

Rabbits are mostly harmless creatures, but occasionally do some damage to agriculture. Rabbits are eaten in many countries; rabbit flesh is extensively canned in Australia. Rabbit hair is often dyed and sold as "seal" or "ermine" fur. Rabbits suffer from a disease *tularemia*, similar to spotted fever. It is transmitted to man by the bite of rabbit lice or ticks. The symptoms of this disease include chills, fever, headache, body pains, vomitting, swellings and glandular disturbances, often terminating in death.

STRUCTURE

External feature.—(Fig. 393). The body of the rabbit comprises 1. head, 2. distinct neck, 3. trunk, 4. limbs and 5. tail. It is covered by hair. The head has a cranial and a facial part. The mouth is bounded by an upper and a lower lip. The upper lip is cleft into two and is characteristically called "hare-lip" There is a prominent

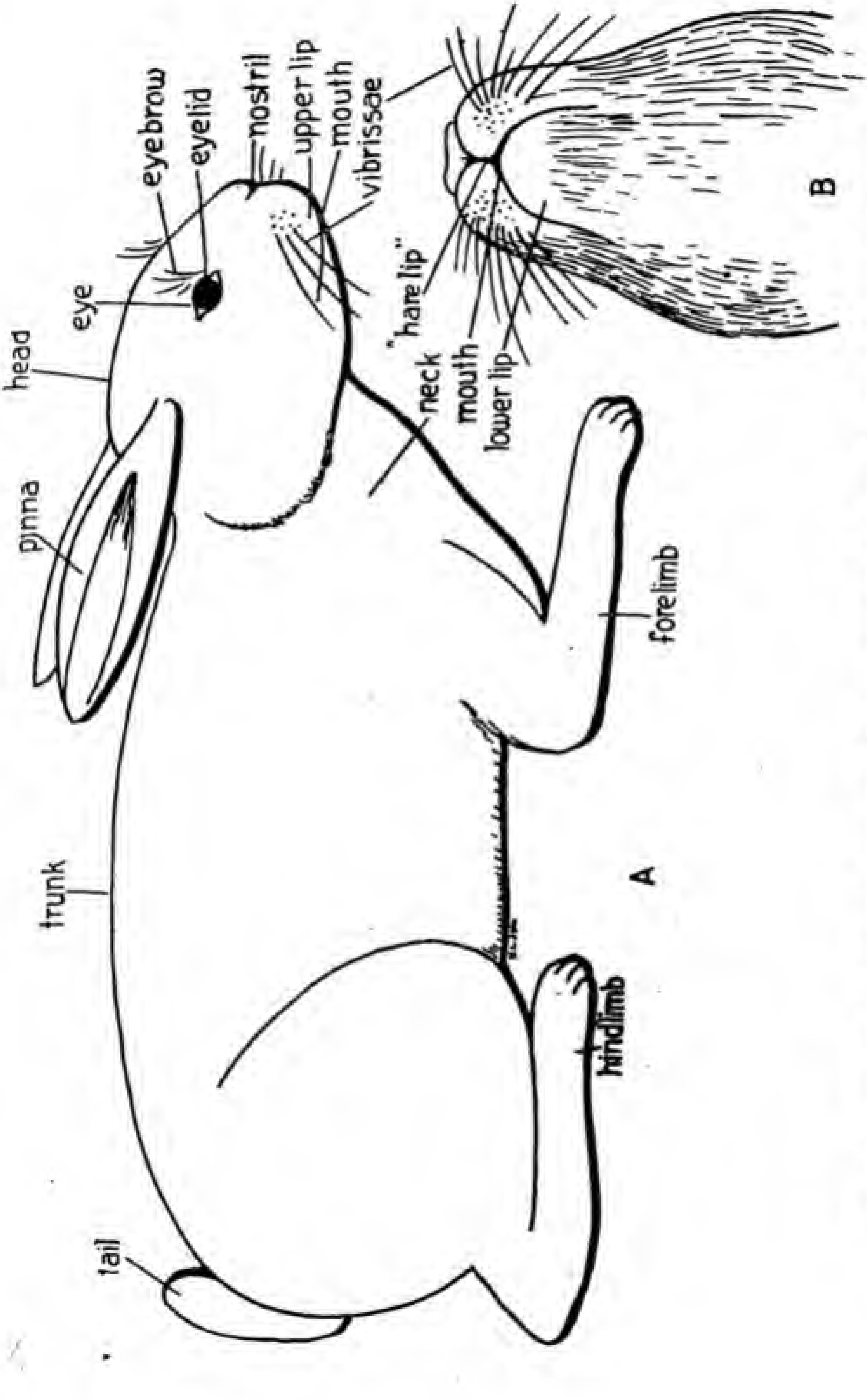


FIG. 393. The rabbit. External features. A. Lateral view of body. B. Ventral view of the head.

cheek. The nostrils are connected with the cleft in the upper lip. The eyes have movable upper and lower eyelids. The nictitating membrane is a small fold in the anterior angle of the eye. The two eyes look laterally and the rabbit does not possess *binocular* vision as in man. The external ear or the ***pinna*** is long. ***Vibrissae*** are found on the sides of the snout and round the eyes. The neck permits free movement of the head.

The trunk comprises the ***thorax*** and the ***abdomen***. The fore limb forms an angle, the ***axillary fossa*** or arm pit with the trunk. The ***inguinal fossa*** separates the hind limb from the pelvis. The ***anal aperture*** lies below the base of the tail. The ***urinogenital aperture*** is separate and opens in front of the anus. The space between the anal and the urinogenital openings is called the ***perineum***. In the male, the urinogenital aperture is at the tip of the penis. The penis is enclosed in a fold of skin called the ***prepuce***. The ***scrotum*** on either side of the penis encloses the testes. In the female, the urinogenital aperture is the ***vulva*** enclosed by folds of integument. The ***clitoris***, the vestigial penis, is a rod-like structure in the vulva. The ***mammary teats*** are eight to ten pairs on the chest and belly. The limbs are built on the same plan as in the frog, but the digits end in nails, modified as horny ***claws*** and are not webbed. There are five fingers on the fore limbs but only four toes on the hind legs. The fore limbs help in burrowing and the hind limbs in the characteristic mode of locomotion.

COMPARISON WITH THE FROG

The external features that are common to the rabbit and frog are :

1. Bilateral symmetry.
2. Differentiation of head, trunk and limbs.
3. Presence of two laterally directed eyes.
4. External nostrils on the snout.
5. Plan of build of the limbs.

The rabbit differs from the frog in the possession of :

1. Hairy covering on the dry skin.
2. A distinct neck.
3. A tail.
4. External ear pinna.
5. Movable eyelids.
6. Movable lips.

7. Vibrissae on lips and eyebrows.
8. Testes outside the abdomen in the scrotum.
9. External penis.
10. Separate urinogential and anal openings.
11. Mammary glands.
12. Five fingers and four toes, ending in claws but none webbed.

These differences are correlated with the different modes of life of the rabbit and the frog. Unlike the amphibious frog, the rabbit is a completely terrestrial animal. It feeds exclusively on vegetable food, is warm-blooded and brings forth young rabbits that are suckled with the mother's milk.

INTERNAL MORPHOLOGY

The body cavity. - The body cavity is divided by a transverse muscular ***diaphragm*** into the ***thoracic*** and ***abdominal*** cavities. The thoracic cavity contains the heart, the lungs and a part of the oesophagus. It is lined by a membrane called ***pleura***. The pleura forms a double fold in the middle, dividing the thoracic cavity into right and left halves which contain the lungs. The diaphragm is convex in the thoracic cavity and is lined by the pleura. The thoracic cavity is strengthened by ***ribs***. The abdominal cavity containts the stomach, intestine, liver, pancreas, spleen, kidneys and ovaries. The membrane lining the abdominal cavity is called ***peritoneum*** The diaphragm is concave in the abdominal cavity and is lined by the peritoneum. The peritoneum is folded to form ***mesenteries***, which surround the different organs.

1. DIGESTIVE SYSTEM

The digestive system includes the buccal cavity, the pharynx, oesophagus, stomach, small and large intestines, caecum and the digestive and associated glands.

The buccal cavity has a bony roof, viz. the ***hard palate***, that separates it from the nasal cavity. The internal nostrils open far backward in the pharynx. The tongue is a muscular organ, that is attached to the back part of the floor of the buccal cavity. It projects forward and upward into the oral cavity. The surface of the tongue is covered by numerous ***fungiform papillae*** in front and ***vallate papillae*** behind. The papillae contain the nerve-ends that act as taste buds. Four pairs of ***salivary glands*** open into the buccal cavity.

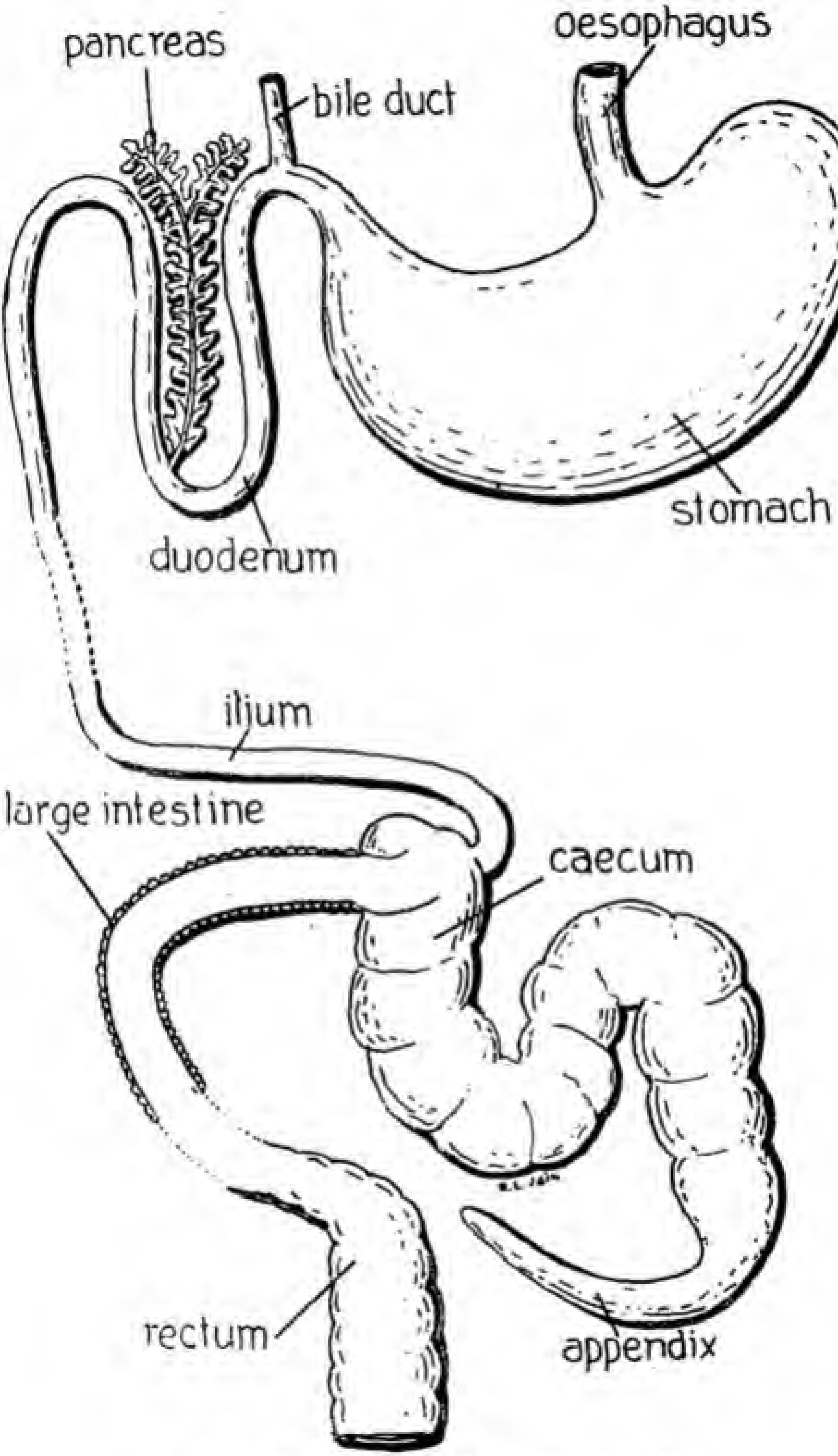


FIG. 394. The alimentary canal of rabbit.

Teeth are present both on the upper and lower jaws. The dentition is ***heterodont, diphyodont*** and ***thecodont***. There are altogether 28 teeth as follows : I 2/1, C 0/0, P M 3/2 and M 3/3. The anterior incisors both in upper and lower jaws are modified into long chisel-like cutting organs. The enamel is largely deposited on the front surface so that these teeth remain permanently sharp. The posterior incisors, the canines and the anterior premolars are absent, leaving ***diastema*** or interval in between. The absence of the intermediate teeth enables the approximation of the lips behind the incisors. The teeth are used for cutting and chewing the food.

The pharynx that succeeds the buccal cavity comprises 1. an ***oral portion*** connecting the buccal cavity with the oesophagus, 2. a ***nasal portion*** into which the internal nostrils open and 3. a ***laryngeal*** portion into which opens the larynx. The ***Eustachian tubes***, that communicate with ear, open in the pharynx. A pair of rounded lymph follicles, the ***tonsils***, lie in the tonsillar depression on either side of the pharynx. A valve-like ***epiglottis***, guarding the entrance to the larynx, projects upwards from the floor of the pharynx. When food is being swallowed, the epiglottis completely closes the ***glottis*** or opening of the larynx to prevent its entry into the wind pipe (Fig. 402).

The oesophagus passes through the neck and thoracic cavity. It lies between the heart and the dorsal aorta. It passes through the diaphragm to enter the abdominal cavity. Here it opens into the stomach, placed transversely on the left side of the abdomen. The cardiac end of the stomach is wide and the pyloric end narrow. The pyloric valve is a ***sphincter*** that guards the entry into the duodenum. The mucus lining the inner surface of the stomach is raised into numerous folds called ***rugae***. The mucus is also rich in ***gastric glands***. The ***pylorus*** opens into the long, coiled small intestine. ***Duodenum***, the first portion of the small intestine is a U-shaped loop (Fig 394). The ***common bile duct*** opens dorsally into the duodenum. The ***pancreatic duct*** opens into the posterior part of the duodenum. The next part of the small intestine is the thick-walled ***jejunum***, which is followed by the thin-walled ***ilium***. The ilium ends in a spherical swollen ***sacculus rotundus***, peculiar to the rabbit. The mucous lining of the innner surface of the small intestine is covered by numerous minute finger-like ***villi*** that help absorption of the digested food. The villi include blood capillaries and lymph vessels

called ***lacteals***. The blood capillaries absorb sugars, amino acids and minerals. The lacteals absorb the soaps, glycerol, etc. of fat digestion.

The sacculus rotundus opens into the large intestine. This opening is guarded by valves. The large intestine is about four feet long and comprises three portions. The first portion, the ***caecum*** or the ***blind intestine*** is connected with the large intestine proper in the sacculus rotundus. The caecum is a long spirally twisted tube ending in a slender finger-like ***vermiform appendix***. The inner mucous lining of the caecum is twisted into the ***spiral valve***. The caecum may serve as extra length of the intestine for more

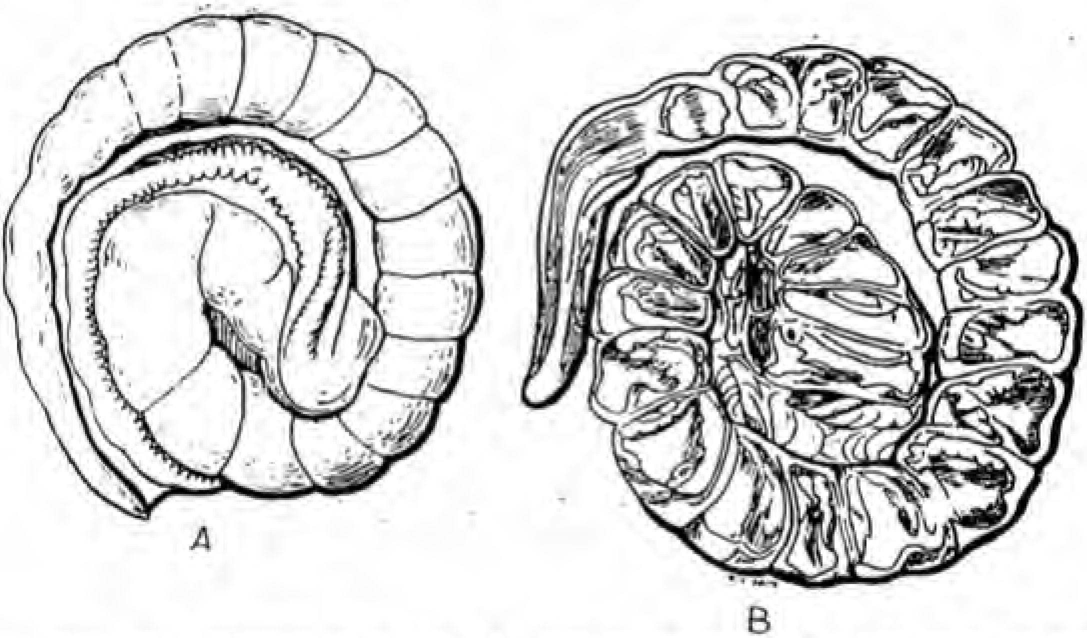


FIG. 395. Caecum of rabbit. A. The entire organ. B. Cut open to show the spiral valve inside.

complete absorption of the digested food. It may also secrete special enzymes for digestion of cellulose. It is large in the rabbit and other herbivorous mammals. It is short and vestigial in the Carnivora and man. It may be removed surgically as in appendicitis operation. The large intestine proper comprises a ***colon*** and the ***rectum***. The colon is divisible into ascending, transverse and descending portions. The ascending colon extends from the sacculus forward to the right side of the body wall. The transverse colon extends across from the right to the left. Here it bends backward to continue into the descending colon. This latter passes backward to the rectum. The rectum leads behind to the ***anus***, which is guarded by a ***sphincter***.

Glands associated with the digestive tract.—The salivary glands, the liver and the pancreas are the glands that are associated with the digestive tract.

The ***salivary glands*** are large and extensive. They comprise 1. the ***parotid***, 2. the ***submaxillary***, 3. ***sublingual*** and 4. the ***zygomatic*** glands. The parotids are the largest salivary glands and comprise diffuse white masses behind the angle of the mandible. Their ducts open into the buccal cavity opposite the last upper molar tooth. The submaxillary gland is a compact spherical mass, the ducts of which open on the floor of the buccal cavity. The sublingual gland

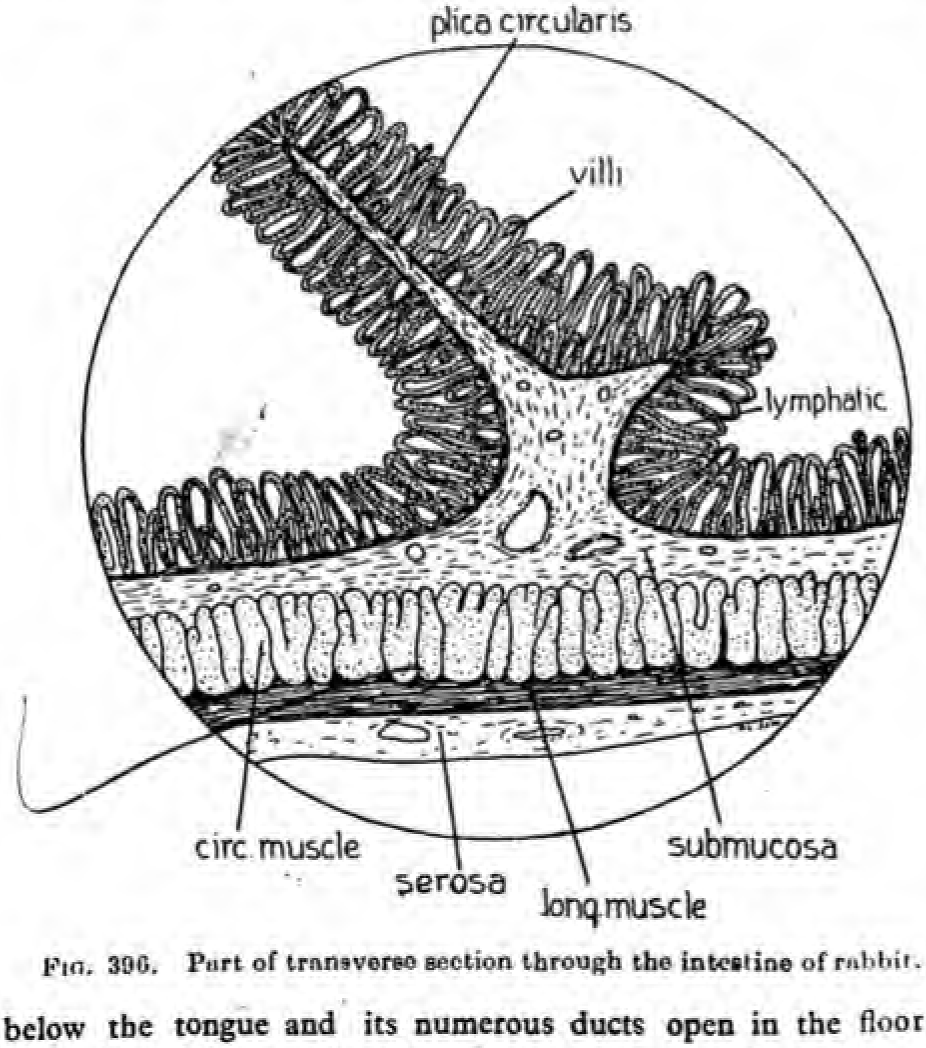


Fig. 396. Part of transverse section through the intestine of rabbit.

lies below the tongue and its numerous ducts open in the floor of the mouth cavity. The small pale yellow zygomatic gland lies in the anteroventral angle of the orbit. Its duct passes downward to open into the mouth on the cheek.

The *liver* is the largest gland in the body. It consists of five lobes. A fold of peritoneum attaches it to the diaphragm. The convex anterior side is close to the diaphragm and the posterior concave side fits on the stomach. The main divisions of the liver are the right and the left lobes; each of these comprises anterior and posterior lobules. The *gall bladder* is situated on the posterior surface of the right anterior lobule of the liver. A number of *hepatic ducts* from the lobules unite with the *cystic duct* from the gall bladder to form the common *bile duct.* The common bile duct passes backward by the side of the hepatic portal vein and opens dorsally into the duodenum directly behind the pylorus.

The liver is a tubular compound gland that is associated with the vascular system in a characteristic manner. Each lobule of the liver is composed of numerous epithelial liver cells arranged radially round a central vein.

The *pancreas* comprises diffuse mass of small lobules in the mesentery connecting the limbs of the duodenal loop. The pancreatic duct opens distally into the duodenum.

COMPARISON WITH FROG

The alimentary system of the rabbit is essentially built on the same plan as in the frog. Because of the differences in the habits and food, the rabbit differs in structure and function as below:

1. The mouth is bounded by movable fleshy lips.
2. The oral cavity has a bony roof (hard palate).
3. Dentition is heterodont and highly specialized. The food is not swallowed whole but is bitten and chewd by the teeth.
4. The tongue is not attached in front of the buccal cavity and cannot be thrust out as in the frog.
5. Digestion actually begins in the oral cavity itself. The saliva, containing enzymes like *ptyalin*, is secreted by the salivary glands opening into the buccal cavity. The saliva acts on the carbohydrates of food. There are no salivary glands in the frog.
6. The pharynx is also specialized. The internal nostrils open far backward in it.
7. The common bile duct opens independently of the pancreatic duct into the duodenum.
8. Villi are present in the small intestine.
9. The large intestine is a complex organ and includes an enormous colon not found in the frog.

10. The rectum does not end in cloaca but in the anus. The urinary and genital apertures do not open into the rectum.

2. CIRCULATORY SYSTEM

Blood.—The blood of rabbit is fundamentally the same as that of the frog. Erythrocytes and leucocytes are suspended in the plasma. The erythrocytes of the rabbit, however, differ from those of the frog.

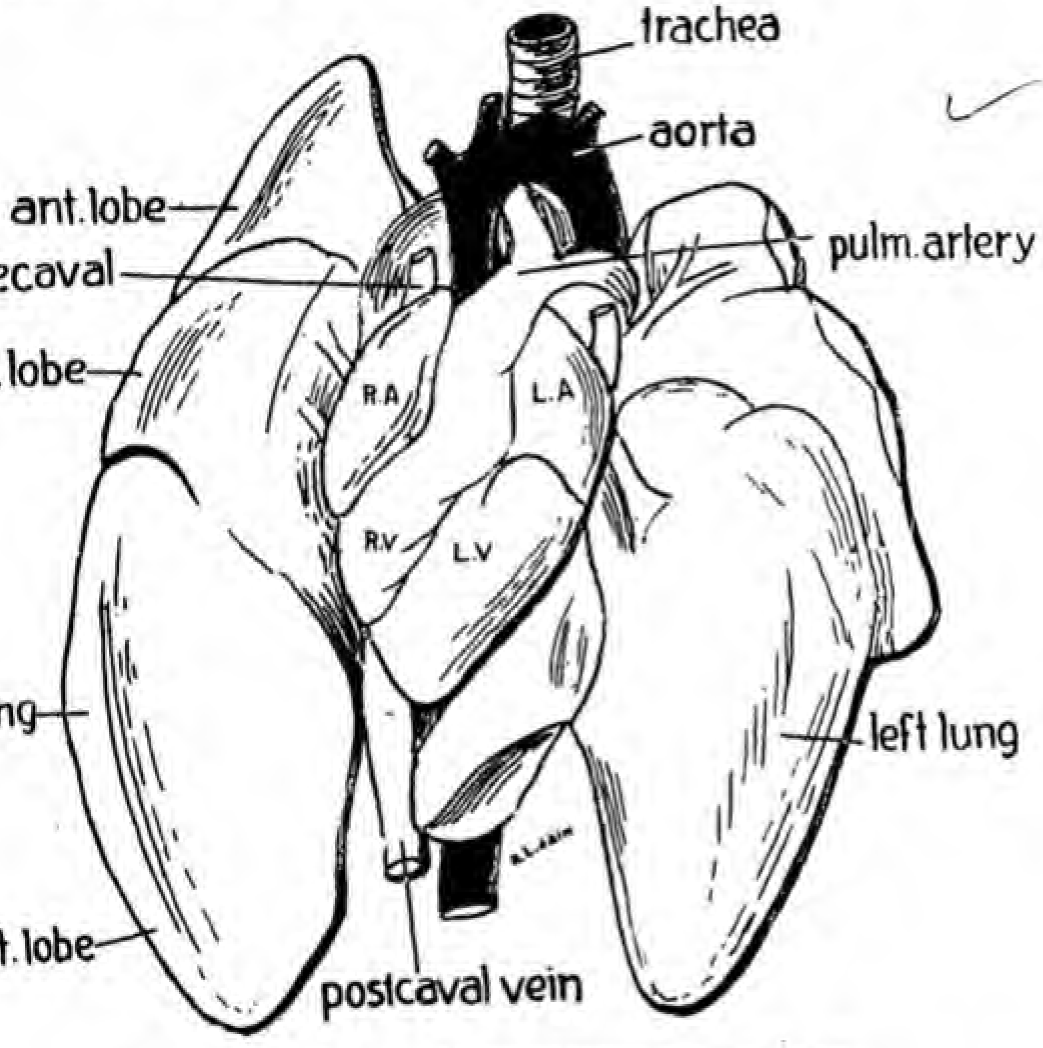


FIG. 397. The heart and lungs of rabbit in ventral view.

They are smaller *biconcave, circular* discs, containing *no* nucleus. The number of the erythrocytes in the blood of rabbit is greater than in man. Each cubic millimetre of rabbit's blood contains over six million erythrocytes. The leucocytes of the rabbit are similar to those of the frog. They are classified as 1. granular or 2. agranular. The granular leucocytes comprise ***neutrophiles, eosinophiles*** and ***basophiles***. The agranular variety includes the ***lymphocytes, monocytes*** and

transitional forms. ***Blood platelets*** comprise the non-nucleated cytoplasmic bits derived from the breaking up of the cells in the bone marrow. They help coagulation and healing or sealing up of small openings in the vessels.

Organs of circulation.—The organs of circulation include 1. the heart, 2. the arteries, 3. the capillaries and 4. the veins.

Heart.—The heart is situated between the two lungs. It is enclosed in a ***pericardium***. The pericardium is made of two layers: the ***parietal*** layer that lines the inner surface of the pericardial chamber and the ***visceral layer*** or ***epicardium*** intimately attached to the heart. The pericardial space between these two layers is filled with the pericardial fluid.

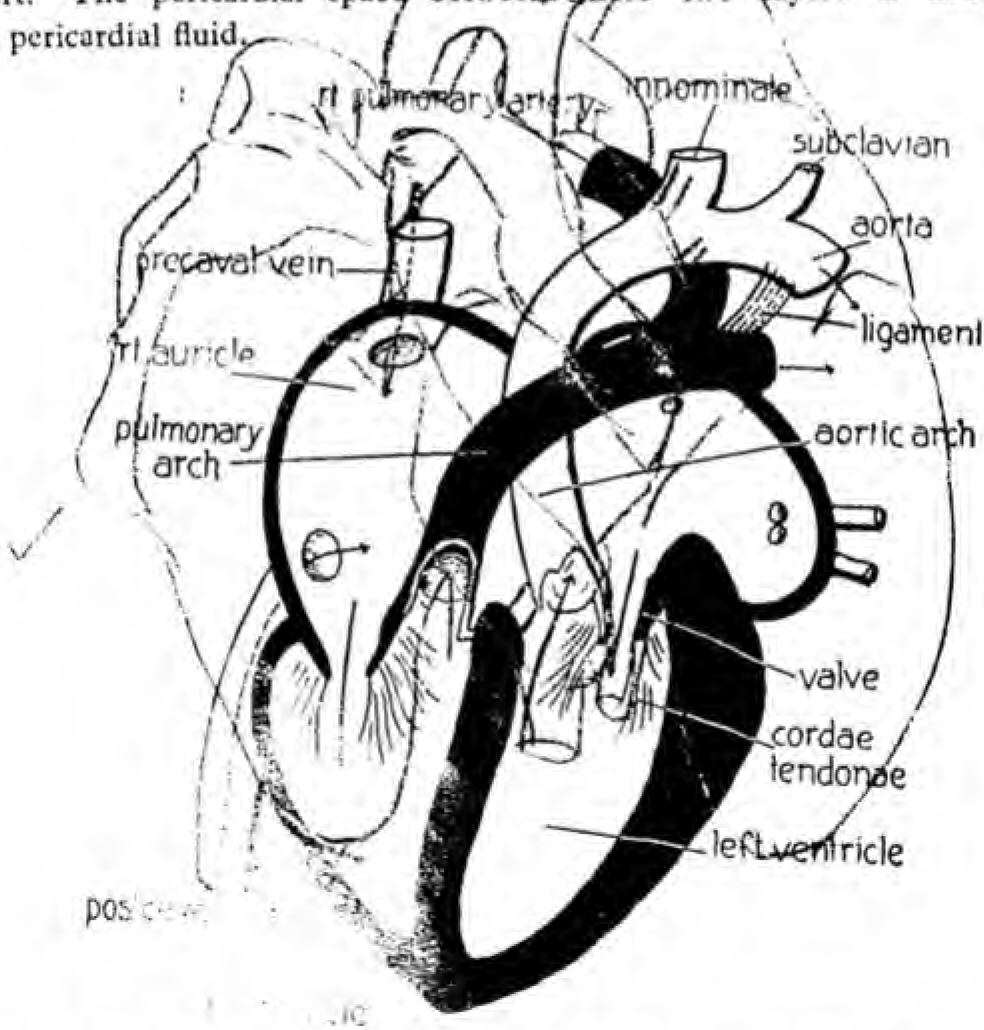


FIG. 398. Diag[illegible] [illegible]itudinal section through the heart of rabbit to show the structure [illegible] [illegible]rows indicate the direction of flow of blood.

There is neither sinus venosus nor conus arteriosus. The heart is completely divided into right and left sides. Each side consists of

a receiving chamber, the ***atrium*** or ***auricle*** and a delivering or distributing chamber the ***ventricle***. The heart has therefore four chambers: two

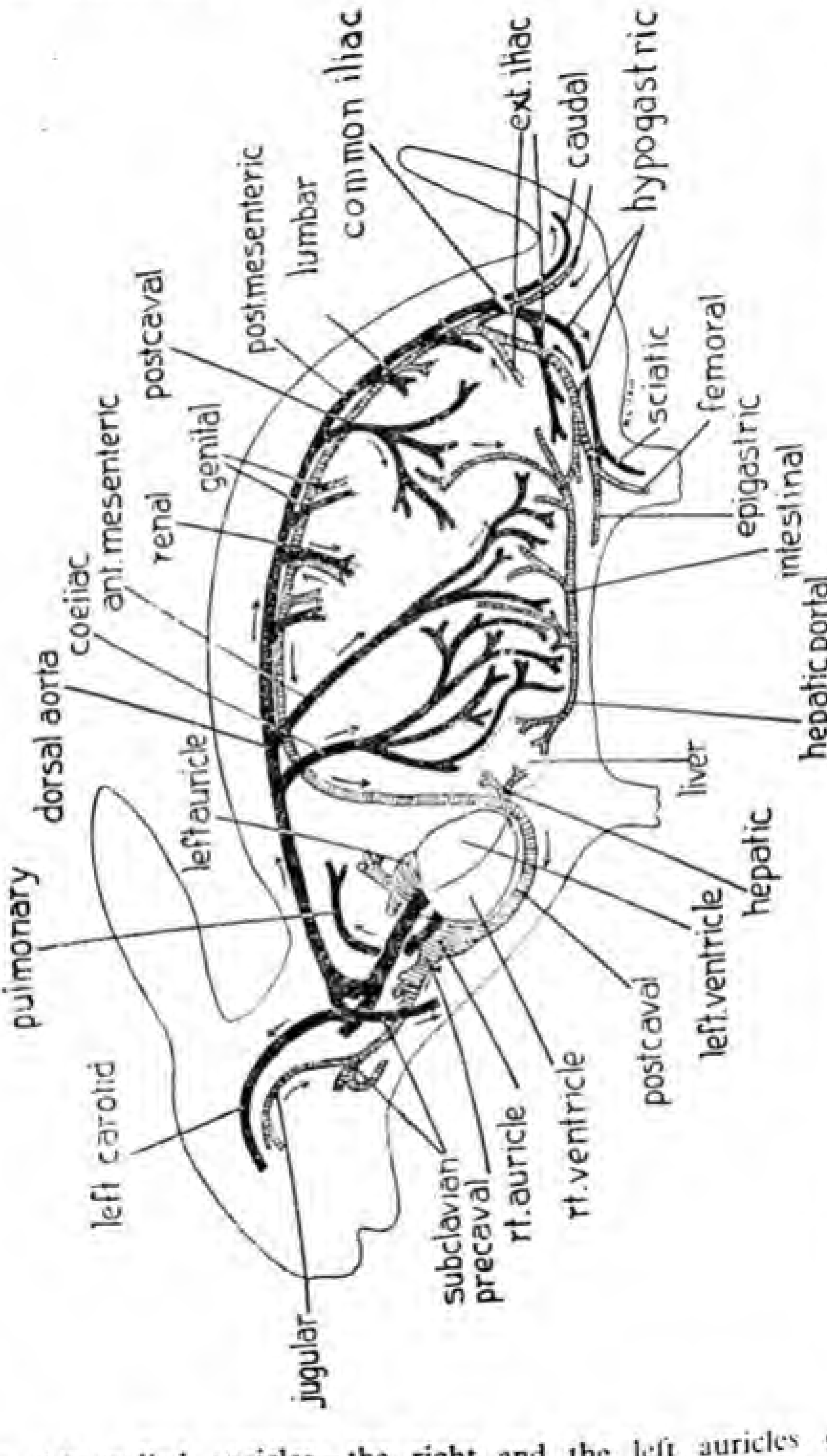


FIG. 369. Diagram of the more important blood vessels of the rabbit. (Arteries black and veins striped.)

anterior thin-walled auricles—the right and the left auricles completely separated onet from another—and two posterior thick-walled ventricles the right and left ventricles also completely separated one from another.

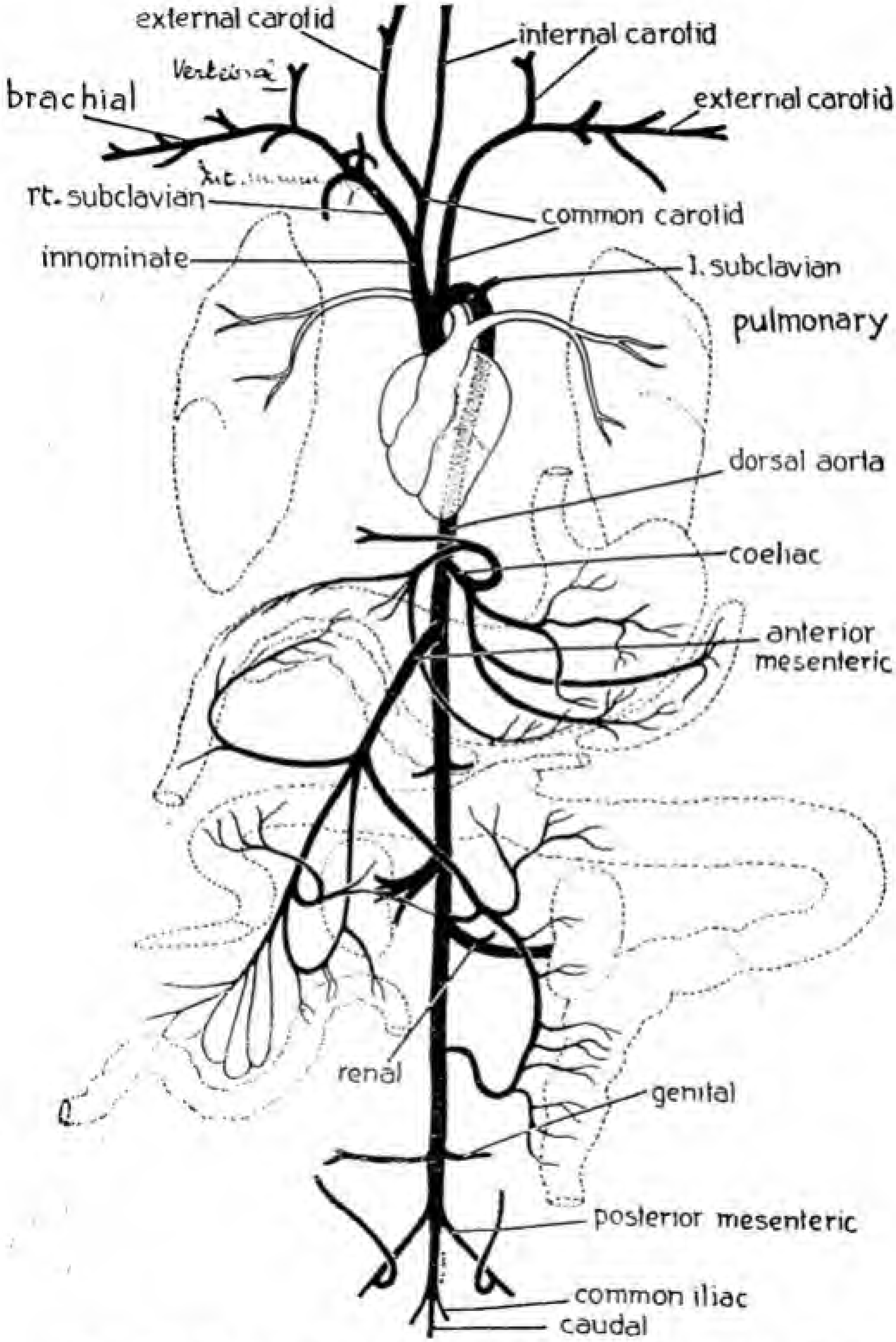


FIG. 400. Diagram of the arterial system of rabbit in ventral view.

The right auricle is thin-walled and communicates behind with right ventricle. It receives the right and left superior vena cava and the unpaired posterior vena cava. The left auricle is also a thin-walled sac that communicates behind with the left ventricle. It receives the pulmonary veins. The wall of the right ventricle is thicker than that of the auricles. The pulmonary artery arises from it. The left ventricle is highly muscular and has the more solid wall of the two ventricles.

The cavities of the two auricles are separated by the ***auricular septum***. In the right auricle, the opening of the right precaval vein is anteriorly on the right side, the opening of the left precaval posteriorly on the left and that of the post caval on the dorsal side. An oval ***fossa ovalis*** in the thin interauricular septum indicates the site where an opening existed in the heart of the embryo. The ***Eustachian valve***, a membranous fold, extends from the opening of the postcaval vein to the fossa ovalis. There is a single opening for the left and right pulmonary veins in the left auricle. The thick muscular walls of the ventricles project into the ventricular cavity as conspicuous ridges called ***trabeculae carneae*** or ***columnae carneae***. The ***pulmonary arch*** arises anteriorly on the left from the right ventricle. The opening of the ventricle into the pulmonary arch is guarded by three pouch-like ***semi-lunar valves***, that permit the flow of blood only from the ventricles into the arch but not backwards. The ***aortic arch*** arises anteriorly from the left ventricle and its origin is also guarded by semi-lunar valves opening only into the aortic arch. The right auriculo-ventricular opening is guarded by ***tricuspid valves*** (more correctly right auriculo-ventricular valves). These valves consist of only two thin membranous flaps, with their free margins projecting into the ventricular cavity. Their free margins are connected by slender fibres, the ***chordae tendonae***, with the ***papillary muscles***. The papillary muscles are thick muscular conical projections from the inner surface of the ventricle. The left auriculo-ventricular aperture is guarded by ***bicuspid*** or ***left auriculo-ventricular valves***.

Arterial system.—There are two arterial circulations in the rabbit—a long or systemic and a short or pulmonary. The former conveys the blood from the left ventricle to the various parts of the body and the latter from the right ventricle to the lungs.

A single ***systemic arterial trunk*** arises from the left ventricle. It corresponds to the left systemic arch of the frog. It is also called the ***aortic arch*** or simply ***aorta***. After passing forward a short distance,

it bends round the bronchus to the left, upward and then backward. Then it continues straight backward directly below the vertebral column as the ***dorsal aorta*** the whole length of the body.

The right and left ***coronary arteries*** arise from the aorta just beyond its origin. The left coronary passes backward on the ventral surface of the heart. The right coronary passes similarly to the right side of the heart between the right auricle and the right ventricle. The two coronary arteries supply blood to the muscles of the heart. Although it contains arterial blood in its left ventricle, the heart cannot directly take it. It has thus its own separate blood supply. It may be likened to a cashier in a bank handling considerable money, but has his own salary.

The ***innominate artery*** arises on the right side of the aortic arch. It divides into (a) the right ***subclavian*** and (b) the right ***common carotid arteries.*** The left common carotid arises separately to the left of the innominate or from its base. The left subclavian arises some distance further along the aortic arch.

The subclavian arteries pass to the first rib, where they become the ***axillary artery.*** The axillary artery continues as the ***brachial artery,*** which divides into the ***radial*** and ***ulnar*** arteries in the fore leg. Proximally, the subclavian artery gives off :— 1. the ***vertebral*** artery, 2. ***superficial cervical*** artery, 3 ***supreme intercostal*** artery and 4. ***internal mammary*** artery. The vertebral artery enters the transverse foramen of the sixth cervical vertebra and runs forward through the neck to the interior of the cranium. It supplies blood to the brain. The superficial cervical artery passes forward and outward and supplies blood to the muscles of the neck. The supreme intercostal supplies branches to the muscles of the ribs. The internal mammary artery passes on the ventral wall of the abdomen as ***epigastric*** artery.

The common carotid artery passes forward by the side of the trachea. At about the level of the larynx in the neck it divides into 1. the ***internal carotid*** and 2. the ***external carotid.*** The internal carotid supplies blood to the brain. The external carotid supplies blood to the face and head.

In the abdomen the dorsal aorta continues as the ***abdominal aorta*** and gives off 1. the ***phrenic***, 2. ***coeliac***, 3. ***mesenteric***, 4. ***renal***, 5. ***spermatic*** or ***ovarian***, 6. ***lumbar*** and 7. ***common iliac***. It then continues as the ***caudal*** artery in the tail. The phrenic arteries supply the diaphragm. The coeliac is an unpaired artery that gives off the ***gastric artery*** to the stomach, ***hepatic*** to the liver and ***splenic*** to

the spleen. The hepatic artery gives off a ***gastroduodenal*** branch to the duodenum and the stomach. The mesenteric arteries are two : ***superior*** (anterior) and ***inferior*** (posterior). The anterior mesenteric arises behind the coeliac and supplies blood to the small intestine, pancreas, caecum and colon. The posterior mesenteric artery arises behind the left renal artery and supplies the rectum. The renal arteries are paired vessels that supply the kidneys. The right renal artery leaves the dorsal aorta somewhat in front of the left renal artery. The paired spermatic artery arises near the posterior mesenteric artery. It supplies the testes and related organs in the male. The ovarian artery similarly supplies the ovaries in the female. The lumbar arteries comprise seven pairs distributed to the lumbar region of the body wall. The common iliac arteries are paired vessels, that divide into the ***external iliac*** and the ***hypogastric*** (internal iliac) artery. The external iliac is the larger of the two and becomes the ***femoral artery*** in the legs. The external iliac artery gives off the ***vesicular*** artery to the urinary bladder. The ***uterine*** artery in the female arises from the external iliac artery. The hypogastric artery gives off several branches in the pelvis, which it leaves as the ***sciatic artery.***

The ***pulmonary arch*** arises from the base of the right ventricle. After passing a short distance forward, to the left and dorsad, it divides into the ***right*** and ***left pulmonary*** arteries. At this place the pulmonary artery and the aorta are connected by the ***arterial ligament*** that represents the ductus arteriosus connecting the vessels in the foetus. The pulmonary arteries enter the lung of the respective side.

Venous system.—The venous system of the rabbit comprises 1. the anterior veins, 2 the posterior veins, 3. the hepatic portal and 4. the pulmonary. There is no renal portal circulation in the rabbit.

ANTERIOR VEINS :—The venous blood from the head returns by 1. the ***internal*** and 2. the ***external jugular veins.*** The internal jugular vein brings the blood from the brain. It leaves the cranium by the jugular foramen and runs by the side of the trachea. The external jugular returns the blood from the facial and superficial parts of the head. It is formed by the union of the anterior and posterior ***facial*** veins. It runs superficially in the neck and joins the internal jugular at the base of the neck. At this point the external jugular also receives the ***subclavian*** vein, that returns the blood from the fore limbs. The vessel formed by the union of the two jugulars and the subclavian is the ***precaval vein*** or ***anterior*** or ***superior vena cava.*** The right precaval vein passes directly backward to open anteriorly into the right auricle. The left precaval crosses

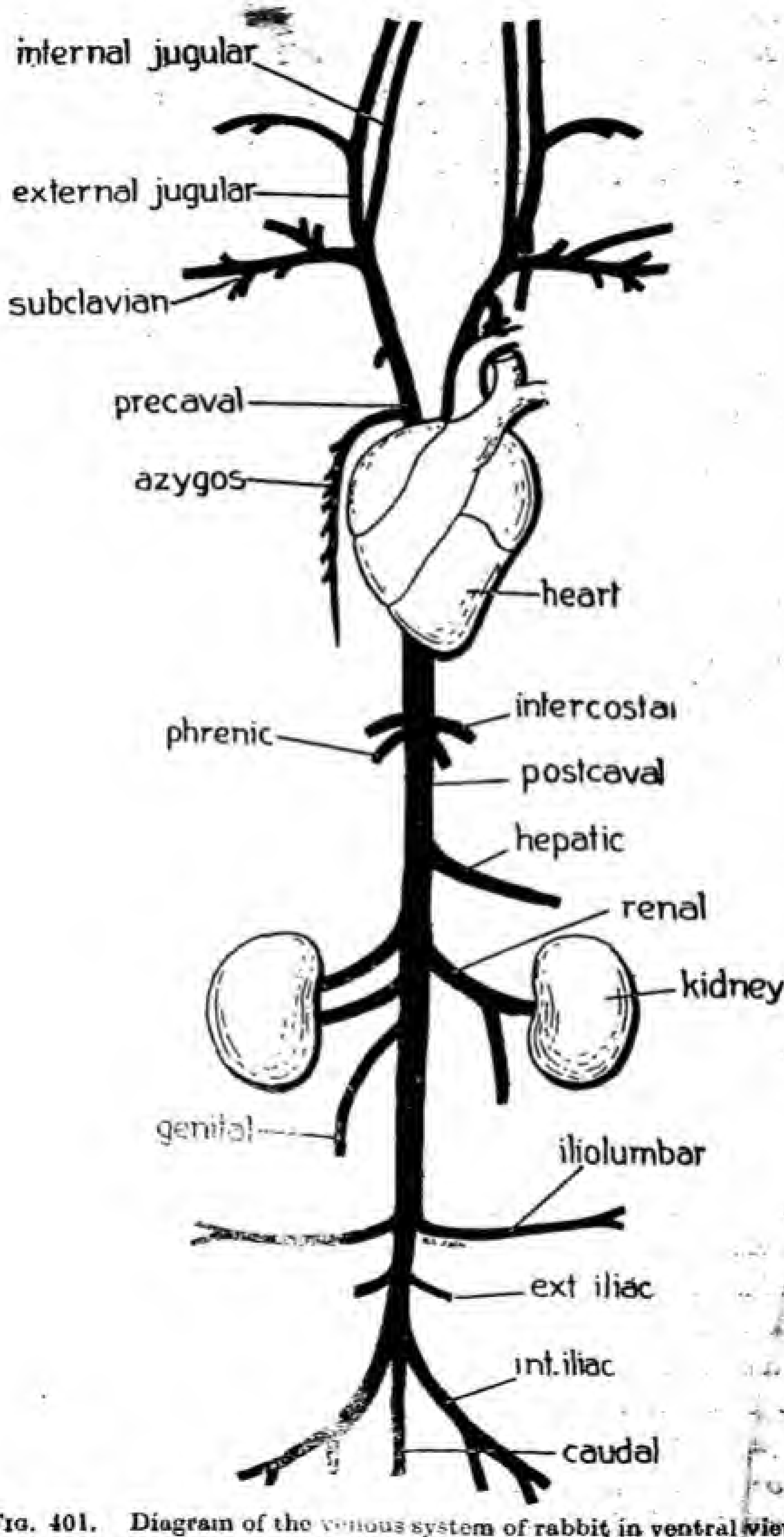


FIG. 401. Diagram of the venous system of rabbit in ventral view.

over the aorta to open somewhat posteriorly into the right auricle. Each precaval vein also receives an ***internal mammary*** (or ***anterior epigastric***) vein from the ventral wall of thorax and an ***anterior intercostal*** from the region of the first four or five ribs. A small unpaired ***azygos*** vein above the aorta brings the blood from the region of the posterior ribs. It opens into the right precaval vein.

POSTERIOR VEINS :—The posterior venous system comprises the postcaval vein and its tributaries. It commences as the ***caudal*** vein in the tail. The caudal vein is joined by a pair of ***internal iliac*** veins from the back of the hind limb. The ***femoral*** vein from the front of the hind limb, the ***posterior epigastric*** vein from the belly, the ***vesicular*** vein from the urinary bladder and the ***uterine*** from the uterus unite together to form the paired ***external iliac*** veins. The external iliac veins join the postcaval in front of the internal iliac veins. The paired ***spermatic*** or ***ovarian*** veins from the genital organs, the paired ***renals*** from the kindneys and the paired ***iliolumbar*** veins from the body wall open into the postcaval. After receiving the ***phrenic*** vein from the diaphragm and the ***hepatic*** vein from the liver, the postcaval vein opens into the right auricle.

The ***hepatic portal*** vein is formed by the union of 1. the ***posterior mesenteric*** vein from the rectum, 2. the ***anterior mesenteric*** vein from the ilium, caecum and the anterior part of the rectum, 3. the ***duodenal*** vein from the duodenum and pancreas and 4. the ***spleneo-gastric*** vein from the stomach and spleen. The portal vein enters the liver, where the blood passes to the ***sinusoids*** or wide spaces in the liver. The hepatic vein returns this blood to the postcaval vein. The blood from the digestive tract containing the absorbed food thus passes first through the liver before entering the heart and general circulation.

The ***pulmonary veins*** convey the freshly oxygenated blood from the lungs. The pulmonary veins of the two sides unite together just before opening into the left auricle on the dorsal surface.

The lymphatic system.—The lymphatic system is an appendage of the venous system. The ***lymph*** contains cells that can migrate through the walls of vessels. The lymph serves the special function of carrying the fat from the intestine. The lymph cells are formed in the spleen, in the bone marrow and from connective tissue cells. They act as phagocytes, ingest and destroy bacteria and disintegrate old red corpuscles.

The lymph circulates in the ***lymphatic vessels***, that open into a large median ***thoracic duct*** discharging into the left precaval vein. The lymph vessels have swollen ***lymph nodes*** or ***glands*** at intervals.

SYNOPSIS OF THE CIRCULATORY SYSTEM

1. The heart is completely four-chambered.
2. The venous stream is completely separated from the arterial stream.
3. Only the left systemic arch is present. This gives off all arteries that supply the head and various other parts of the body.
4. The venous system lacks a renal portal circulation. There is only the hepatic portal circulation.
5. There is no sinus venosus ; the precaval and post caval veins open directly into the right auricle.

COMPARISON WITH FROG

1. The blood of rabbit differs from that of the frog in having smaller, circular and biconcave red corpuscles. They do not also have nuclei.
2. The ventricle is completely separated, so that there is no mixing of the venous and arterial blood.
3. In the frog there are three aortic arches : the carotids, the systemic and the pulmocutaneous are paired vessels that arise as separate arches from the truncus arteriosus. In the rabbit there is only one aortic arch – the left systemic arch, from which the carotid artery arises. The pulmonary artery arises independently from the right ventricle.
4. In the frog there are two portal—the renal and hepatic—systems, but in the rabbit the renal portal system is absent.
5. In the frog the veins open into the sinus venosus but in the rabbit they open directly into the right auricle.

5. RESPIRATORY SYSTEM

The respiratory organs consist of 1. the paired ***lungs***, 2. the ***true respiratory tract***, 3. the ***accessary respiratory tract***, 4. the ***diaphragm*** and 5. the ***intercostal muscles***.

The lungs of the rabbit are not simple hollow sacs as in the frog. They are highly elastic, very greatly ramified saccular gland-like bodies, with a spongy appearance. The internal surface is in contact with air. They are situated one on either side of the heart. Each

lung comprises anterior, middle and posterior ***main lobes.*** The left lung is smaller than the right lung. The right lung has also two additional anterior and posterior ***azygos lobes.*** The lungs are surrounded by a thin membrane called the ***pulmonary pleura.*** Posteriorly the lungs are attached to the diaphragm by the ***pulmonary ligament.*** The elasticity of the lungs is increased by the smooth muscles in its connective tissue.

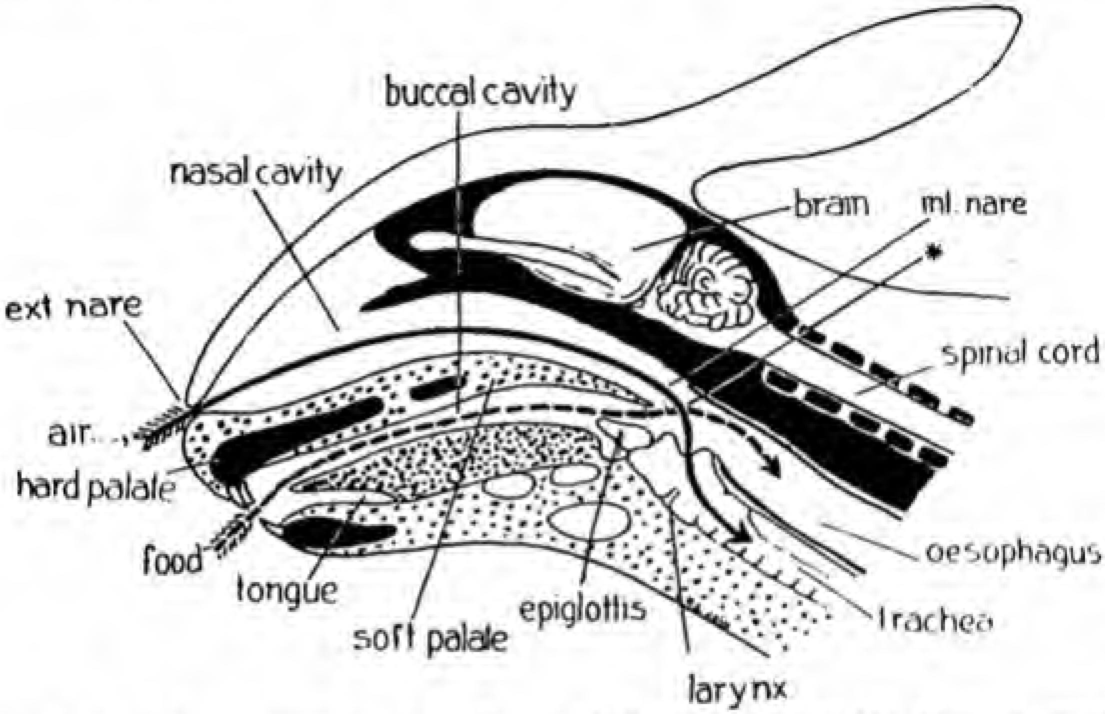


FIG 402. Diagrammatic median vertical section through the head of rabbit to illustrate the chiasma or crossing of the respiratory and food channels at *. (Bones are shown black).

The true respiratory tract comprises 1. the larynx 2. the trachea and 3. the bronchi. The ***larynx*** or the ***voice box*** is composed of incomplete rings of cartilages. The ***thyreoid*** cartilage is the largest; it is a saddle-shaped piece, produced forwards and backwards dorsally into horn-like processes. The ***cricoid*** cartilage lies behind. A paired ***arytenoid*** cartilage is closely associated with the cricoid in front. The ***vocal cords*** are rudimentary in the rabbit. They are a pair of elastic folds of mucous membrane stretched across the cavity of the larynx. One end of the cords is attached to the thyreoid cartilage and the other end to the arytenoid cartilage. The ***glottis*** or the opening of the larynx into the pharynx is guarded by the ***epiglottis***.

The larynx continues behind into a long trachea that lies in the median line below the oesophagus. It is composed of cartilagenous

tracheal rings, each of which is incomplete dorsally. In the thorax the trachea divides into right and left ***bronchi***. Each bronchus enters the lung of that side. The bronchi divide into several ***bronchioles***, that ramify again and again to produce a complex system of ***alveolar ducts*** (Fig. 403). The ducts branch to ***atria***, these to ***alveolar sacs***

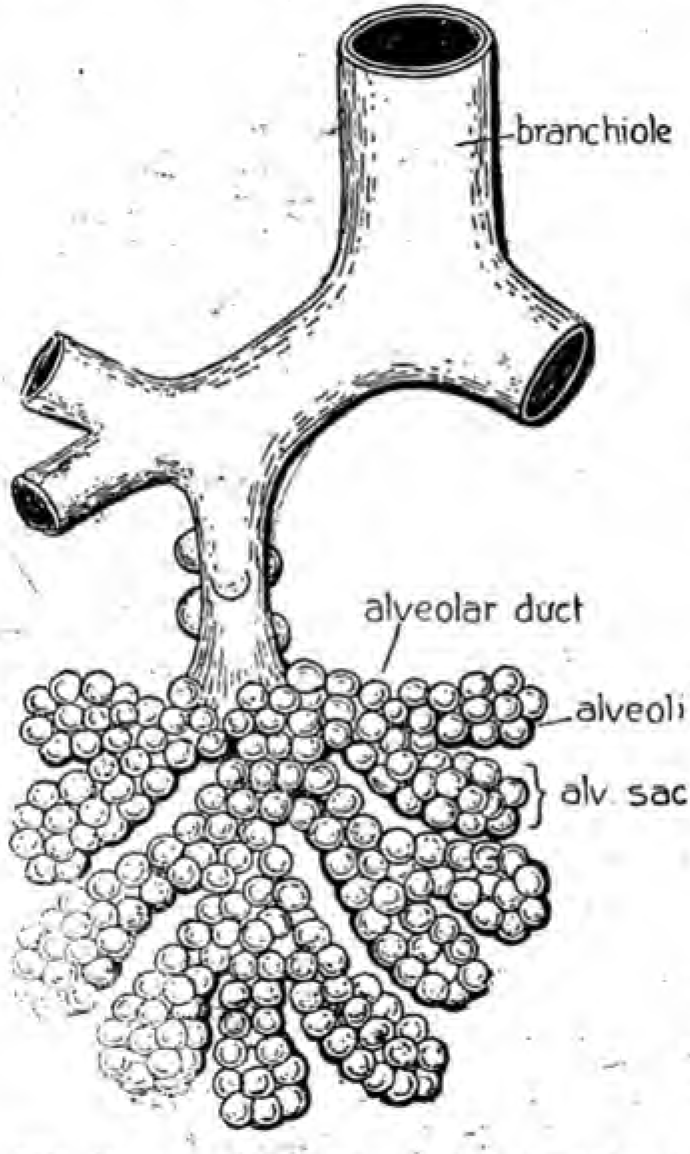


Fig. 403. Diagram of the structure of the lung of a mammal.

and ultimately the *alveoli* or the air spaces of the lungs. The alveoli are richly supplied by blood capillaries. The bronchioles have less and less cartilage until the finer branches lack the cartilage. Each alveolus of the lung of the rabbit really represents a single lung of the frog.

The accessory respiratory tract includes the ***nostrils*** and the ***nasal*** passage. The nasal cavity is separated from the oral cavity by the hard palate in front and soft palate behind. It opens into the back part of the pharynx by the internal nostrils. The function of the nasal passage is to warm the air and remove particles of foreign matter from it before it goes into the lungs. The nasal passage has scrolls of mucous covered bones that efficiently carry out both these functions. In the pharynx there is thus a ***chiasma*** (Fig. 402) or crossing of the respiratory and food channels.

Mechanism of respiration. –The lungs completely fill the air-tight pleural cavities of the thorax. Inspiration or entry of air into the lungs is effected by the expansion of the thoracic cavity. Expiration or expulsion of the air is brought about by its contraction. Contraction of the external intercostal muscles (the external muscles between the ribs) raises the obliquely set ribs, thus expanding the chest cavity. Simultaneously the phrenic muscles contract, flatten the dome-shaped diaphragm and incidentally displace the abdominal viscera. These two movements, the rising of the chest wall and the flattening of the diaphragm, expand the lungs and draw in fresh air through the nostrils. With the relaxation of the intercostal and phrenic muscles, the ribs and the diaphragm return to their original position and cause contraction of the thorax. The elastic lungs contract and force the air out. The buccal cavity plays no active part in breathing. The respiratory movements in the rabbit are thus different from those of the frog. The throbbing movement of the throat in the frog *forces* the air in and out of the lungs. In the rabbit, however the air is *sucked* in and out by the alternate expansion and contraction of the elastic lungs caused by those of the thorax.

The contraction of the internal intercostal muscles and of the abdominal muscles diminishes the capacity of the chest. Such sudden contractions cause a violent expiration as in *coughing*. The sound of the cough is due to the violent opening of the epiglottis. A *sigh* is a deep laboured inspiration brought about by the contraction of the muscles attached from the vertebral column and neck to the ribs.

4. URINOGENITAL SYSTEM

As in the frog, the organs of excretion and of reproduction constitute the urinogenital system of the rabbit. The urinary and the reproductive systems are associated by having a common duct for the passage of their products—urine and the ova or sperm. In both the

sexes, this association exists in the ***urinogenital canal***, that opens not into the digestive tract to form a cloaca as in the frog, but separately to the outside.

Urinary system.—The ***kidneys*** are the chief organs of the urinary system. They are paired, bean-shaped (*reniform*) organs, flattened dorsoventrally, convex laterally, concave medially, and lying against the dorsal wall of the peritoneal cavity in the abdomen. The right kidney is considerably in front of the left. The concavity is termed the ***hilus*** (Fig. 4c4). From the hilus a white tube, the ***ureter***,

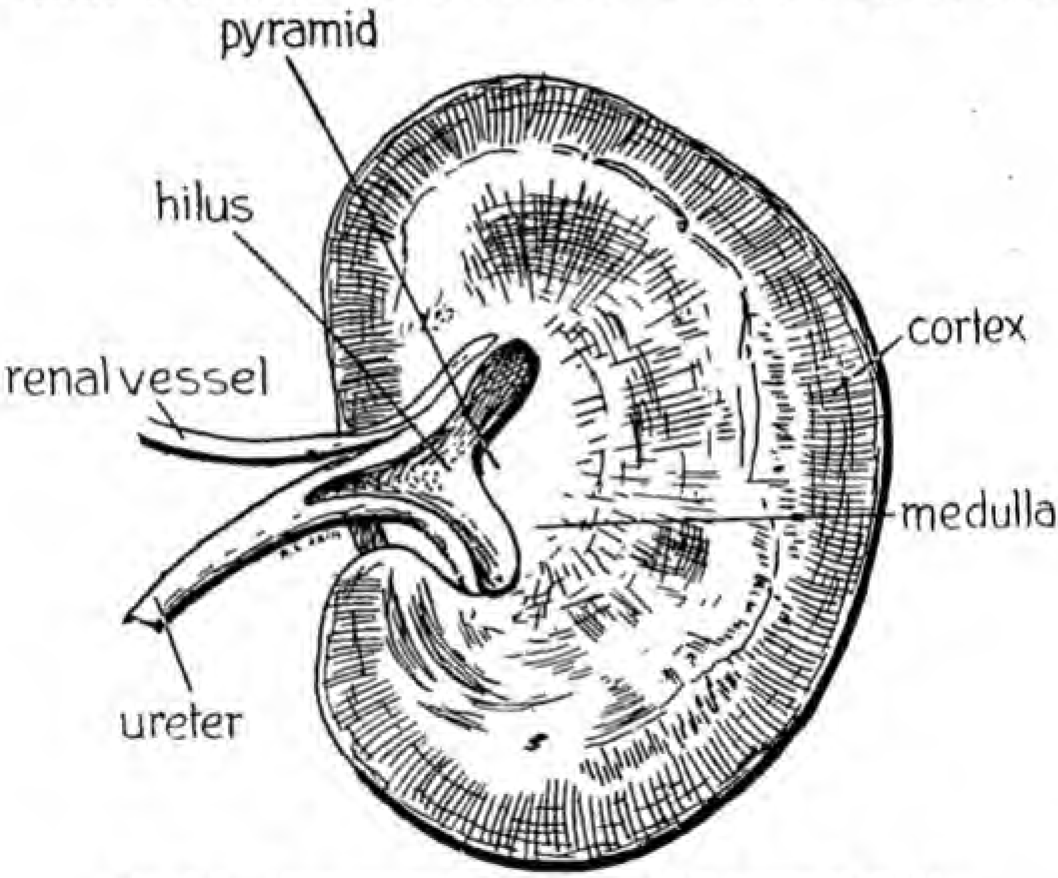


FIG. 404. Longitudinal section through the kidney of rabbit.

passes backward to open into the ***urinary bladder***. The renal artery enters the kidney and the renal vein leaves it at the hilus. Within the hilus is a cavity, the ***renal sinus***, that is occupied by the renal artery and vein and by the ***renal pelvis*** or the expanded first part of the ureter. The substance of the kidney projects into the renal pelvis as the ***renal papilla***. The microscopic openings of the urine collecting tubules are located on the renal papilla. The collecting tubules and the renal papilla together constitute the ***renal pyramid***. There is only one pyramid in the rabbit but twelve in the human kidney.

The kidney has a fibrous coat, surrounded by an ***adipose capsule*** or fat. The substance of the kidney comprises an external granular and more vascular ***cortex*** and a central, somewhat radially striated ***medulla.*** The substance is essentially composed of a system of ***renal***

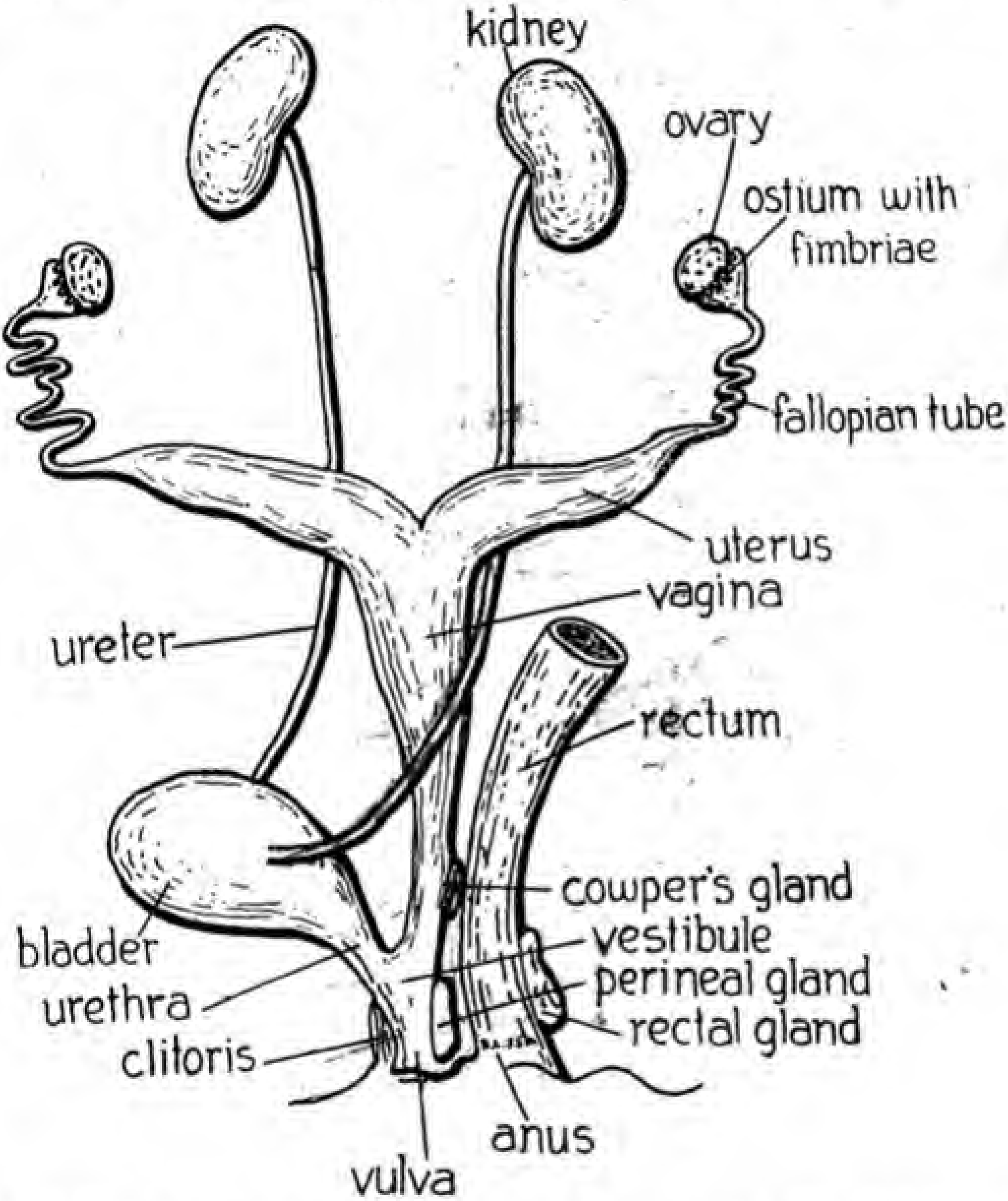


FIG. 405. Internal reproductive organs and associated structures of the female rabbit.

tubules. Each tubule begins in the cortex in the ***malpighian corpuscle.*** The malpighian corpuscle is a double capsule enclosing the ***glomerulus*** or a coiled mass of capillaries from the renal artery. The space between the capsule and the glomerulus continues into the renal tubule. The blood in the glomerulus is separated from this space

by a very thin membrane, that filters the urine into the space. The renal tubules continue into the collecting tubules that open on the renal papilla in the renal pelvis.

The ***urinary bladder*** lies ventrally in the posterior part of the abdomen. It is a pear-shaped muscular sac capable of considerable distension. Its anterior end is the ***vertex***, and the posterior end, the ***fundus***, narrows to the ***urethra***. The genital ducts open into the urethra dorsally to form the ***urinogenital sinus***. The sinus opens to the outside on the ***penis*** in the male and by ***vulva*** in the female.

5. REPRODUCTIVE SYSTEM

The reproductive system of the rabbit includes the essential organs of reproduction, viz. the ***testes*** in the male and the ***ovaries*** in the female, and their ducts.

The male genital organs.—The testes are paired oval bodies. In the young animal they are situated close to the kidneys within the abdomen but at the time of maturity ***descend*** or pass backward into the ***scrotum*** and become inguinal. The descent of the testes into the scrotum takes place in other mammals like man even during the embryonic development.

The scrotum is a loose sac, behind the penis. The scrotal sac is lined by a thin layer of ***cremaster muscle***, continuous with the internal oblique muscles of the abdominal wall. Below this lies the ***parietal layer*** of the ***tunica vaginalis propria***, a layer of peritoneum that is continuous with that of the abdominal wall. The scrotal sac is widely open to the abdominal cavity by the ***inguinal canal***, through which nerves, blood vessels and ducts pass to the testes. The testes and their associated vessels and ducts occupy the scrotal cavity. The testes are suspended from the dorsal wall of the scrotum. A short connective tissue cord called ***gubernaculum*** joins the posterior end of the testes with the end of the scrotal sac. The ***visceral layer*** of the ***tunica vaginalis propria*** forms the peritoneal covering of the testes.

A ***spermduct*** or ***vas deferens*** arises from each testes. The first part of the vas deferens is much coiled and bound up together by connective tissue to form an ***epididymis***. The epididymis is usually imbedded in a mass of fat at the anterior end of the testes. The vas deferens then extends back as a thin cord along the side of the testes. The thick anterior part forms the ***caput epididymidis*** and the slender part near the posterior end of testes forms the ***cauda epididymidis***.

The gubernaculum connects the cauda epididymidis to the scrotal sac. The vas deferens then runs in association with blood vessels and nerves to form an imperfect ***spermatic cord***. The spermatic cord passes through the rather wide inguinal canal. It bends back at the place where

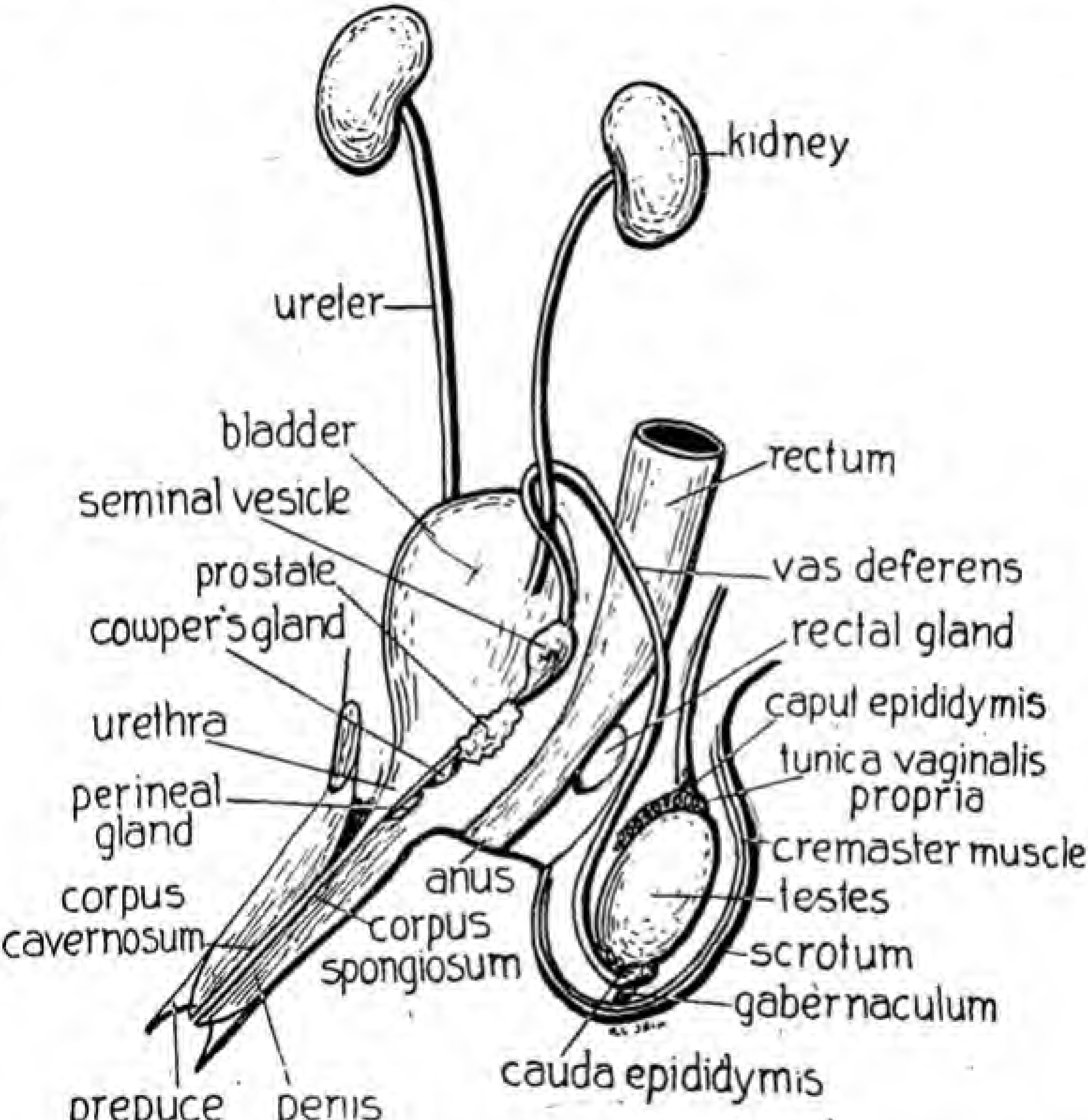


FIG. 406. Internal reproductive organs and associated structures of the male rabbit.

the ureter opens into the urinary bladder. The two ducts open into the ***seminal vesicle*** on the dorsal surface of the bladder. The ***vesicular gland*** and ***prostate gland*** lie dorsally on the posterior part of the seminal vesicle.

The seminal vesicle opens into the ***urethra*** to form the ***urino-genital sinus***. On either side of the base of the seminal vesicle, the outer urethral lining projects as numerous finger-like ***paraprostatic glands***. The bulbourethral or ***Cowper's*** gland is a pink-coloured bilobed mass imbedded in the wall of the urethra behind the prostate. These glands and the seminal vesicle produce the liquid in which the spermatozoa are suspended.

The urinogenital canal continues into the penis to open to the outside. The penis is an erectile organ that is used in copulation. It is formed chiefly by the highly vascular ***corpus spongiosum*** and by a pair of hollow fibrous structures, the ***cavernous bodies***. These have thick white sheaths. Anteriorly, the cavernous bodies diverge, and each is attached to the ischium of the pelvic girdle by a fibrous ***crus penis***. The penis is also attached to the pubic symphysis by a short stout suspensory ligament and by a thick muscle. The entire penis is enclosed in a fold of skin called the ***prepuce***. During copulation the penis is erected by the turgidity of the corpus spongiosum. As a result of the sexual excitement, the blood capillaries dilate and permit an extra amount of blood flow to increase the turgidity.

Female genital organs.—The ovaries are small paired elongate or oval, grey or yellow bodies that lie on the dorsal body wall somewhat behind the kidneys. A fold of the peritoneum called ***mesovarium*** suspends the ovary from the body wall. A mature ovary contains numerous ***ovarian*** or ***Graafian follicles***, that appear as dots on the surface of the ovary. Each Graafian follicle encloses a large ***ovum***, invested by a ***vitelline membrane*** and is surrounded by follicle cells. A fluid-contained clear space appears in each follicle. Finally the Graafian follicle bursts and the ova escape into the abdominal cavity.

The oviducts, which are also called ***Müllerian*** ducts, open close to the ovaries. The first portion of the oviduct is called the ***fallopian*** or ***uterine*** tube. It is a narrow tube, opening anteriorly into the abdominal cavity by a broad funnel-shaped ***ostium***, surrounded by fringes of ***fimbriae***. The ostium is close to the ovary and the fimbriae surround it. The ova that escape from the ovary thus pass into the fallopian tube.

The posterior part of the oviduct is enlarged into the ***uterus***. It is highly muscular and is supported by ligament. The uterus of the two sides cross over to the front of the ureters and meet to form a wide ***vagina*** between the bladder and rectum. The vagina extends

behind and receives the urethra to form the common urinogenital passage called ***vestibule***. The vestibule opens to the outside by the ***vulva***. The vulva is enclosed by the ***labia majora***. The small, rod-like ***clitoris*** is the homologue of the penis of the male. Cowper's glands are present but there is no prostate.

In the rabbit the two uteri are separate. This condition is described as ***duplex uterus***. In man the two uteri are united to form the ***simplex*** type.

Comparison with the Frog

1. The kidneys of the rabbit differ from those of the frog in shape. The hilus and the pyramid are absent in the frog's kidneys. The ureters arise laterally from the outside of the kidneys in the frog. In the rabbit however the ureters arise from the hilus on the median side.

2. The ureters open into the cloaca in the frog but in the rabbit directly into the urinary bladder.

3. The Cloaca forms the common passage for the urinogenital and the alimentary products in the frog. In the rabbit there is no cloaca. The urinogenital ducts open separately from the rectum.

4. The testes always remain within the abdomen in the frog but in the rabbit descend into the scrotum.

5. The testes of the frog are connected to the kidneys by the vasa efferentia, so that the sperm passes through the kidneys and the ureter. In the rabbit however the testes are not thus connected and the sperm passes directly by the vas deferens into the urethra.

6. The male frog has no copulatory organ and fertilization of the ova takes place outside the body. The penis of the rabbit serves as the ***phallic*** or copulatory organ and enables the sperms being shed into the vagina of the female. This ensures internal fertilization and development within the uterus.

7. The oviducts are comparatively simple tubes in the frog. In the rabbit they are modified posteriorly into the uterus in which the entire embryonic development is completed.

8. The ova of the frog are relatively large and contain considerable yolk. They are discharged into the water. The ova of the rabbit are much smaller and are deficient in yolk. They are retained within the uterus.

6. SKELETAL SYSTEM

The skeletal system of rabbit consists of an ***exoskeleton*** and an ***endoskeleton***. The exoskeleton is solely represented by the ***claws*** on

the digits. The claws are scale-like thickenings of the ***stratum lucidum*** between the stratum germinativum and stratum corneum of the skin at the ends of fingers and toes. The endoskeleton comprises the ***axial*** and the

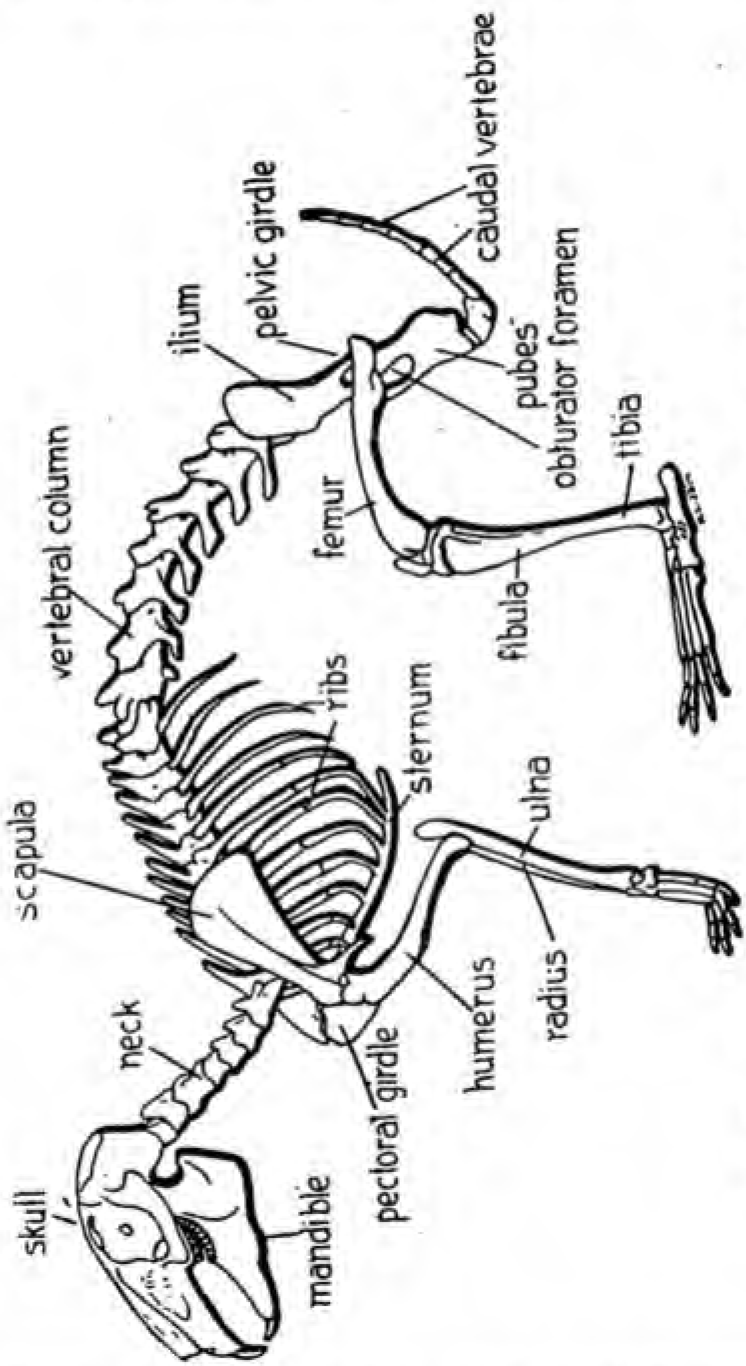


FIG. 407. Skeleton of the rabbit in lateral view from the left in standing posture.

appendicular portions. The skeleton of the head, the vertebral column, the ribs and the sternum constitute the axial skeleton. The limbs and the pectoral and pelvic girdles form the appendicular skeleton.

THE VERTEBRAL COLUMN

The vertebral column of the rabbit is formed of series of ***vertebrae*** : 7 cervical, 12 thoracic, 7 lumbar, 4 sacral and 14 to 16 caudal vertebrae. It is not straight but is curved dorsad in the thoraco-lumbar region The cervical and the caudal regions are curved ventrad.

A typical vertebra comprises a ***centrum*** or vertebral body below and a ***vertebral*** or ***neural arch*** above. The two portions enclose a large ***vertebral foramen*** or vertebral canal. The foramina of successive

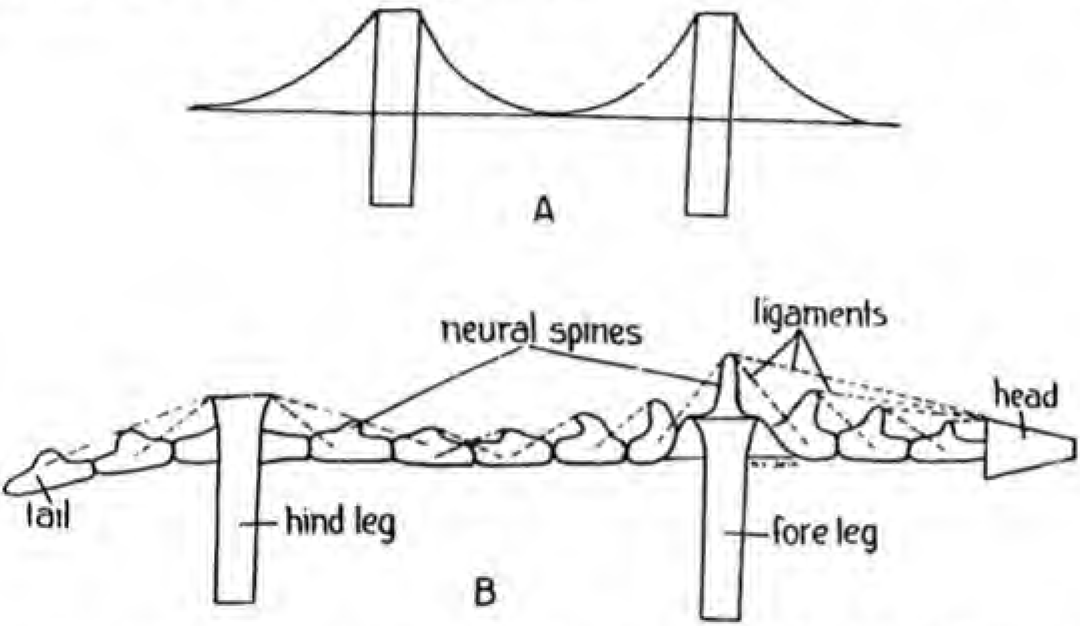


FIG. 408. The axial skeleton (B) of rabbit is essentially a double cantilever bridge (A). The neural spines represent the struts and the muscles (dotted lines) represent the ties of the bridge. (*Adapted from Brazier Howell, Speed in Animals, University of Chicago Press*).

vertebrae form the ***neural canal*** for the spinal cord. The vertebrae are ***platycoelous***, i. e. the centra have flat ends both anteriorly and posteriorly. Intervertebral discs of cartilage separate the centra of successive vertebrae. The part of the neural arch which connects with the centrum is the ***pedicle*** and the rest, ***lamina***, forms the roof of the vertebral canal. The anterior and posterior margins, of the pedicle are notched. Each notch is opposite to that of the adjacent vertebra. They together form the ***intervertebral foramen***, through which the spinal nerve passes out.

The vertebral arch bears the ***transverse process*** horizontally on either side and the ***spinous process*** or ***neural spine*** dorsally. The anterior and posterior margins of the arch bear low articular processes or ***zygapophyses***. The ***prezygapophysis*** or the anterior process is directed dorsally and the ***postzygapophysis*** or the posterior process

points ventrally. The zygapophysies of two succeeding vertebrae are bound together by ligament that strengthens the vertebral column but allows flexibility.

Cervical vertebrae.—The seven cervical vertebrae mainly serve to support the head. The first two cervical vertebrae are specially modified to permit the movements of the head in various directions. The rest are

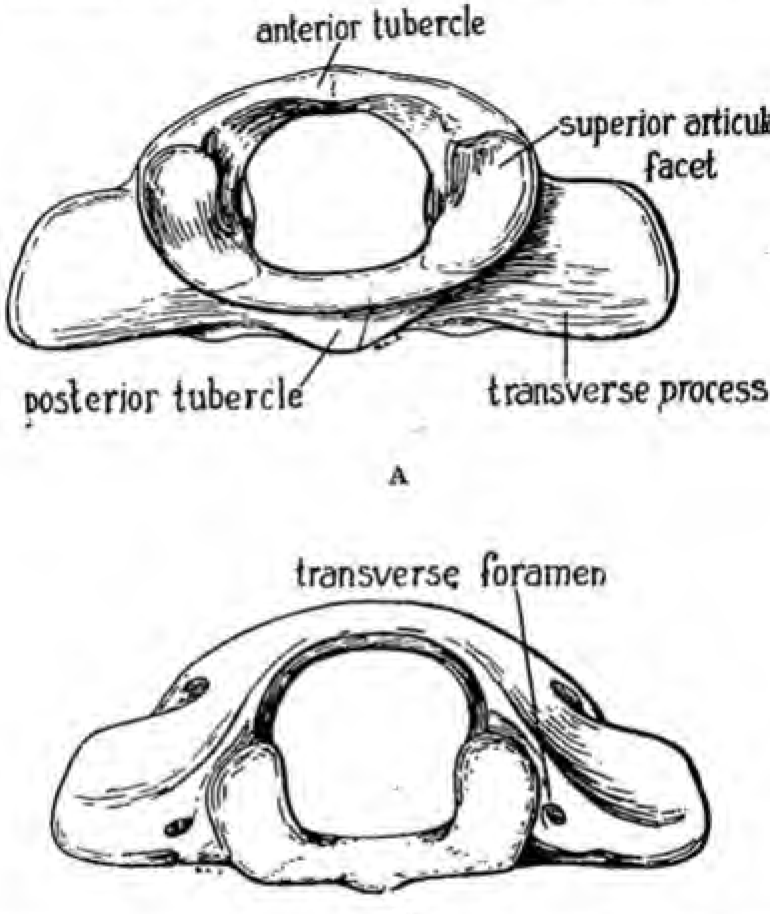


Fig. 409. Atlas vertebra of cat A. anterior view, B. posterior view.

dorsoventrally flattened and have low arches and short spines. The transverse process is perforated by the ***costo-tranverse foramen***, for the passage of the vertebral artery to the head. The ***atlas*** is the first cervical vertabra. It consists of the ventral ***anterior arch***, the dorsal ***posterior arch*** and paired ***lateral masses*** and lacks the centrum. The anterior arch bears the ***anterior tubercle*** below and the posterior arch bears the ***posterior tubercle*** above. Anteriorly on either side the atlas has large concave ***superior articular pits*** for the articulation of occipital condyle of the skull. Small triangular ***inferior articular facets*** on the posterior side articulate with the second vertebra.

The ***epistropheus*** or axis is the second cervical vertebra. It is remarkable for possessing a stout ***odontoid process*** or ***dens epistropheus*** (tooth) in front. The dens represents the centrum of the atlas

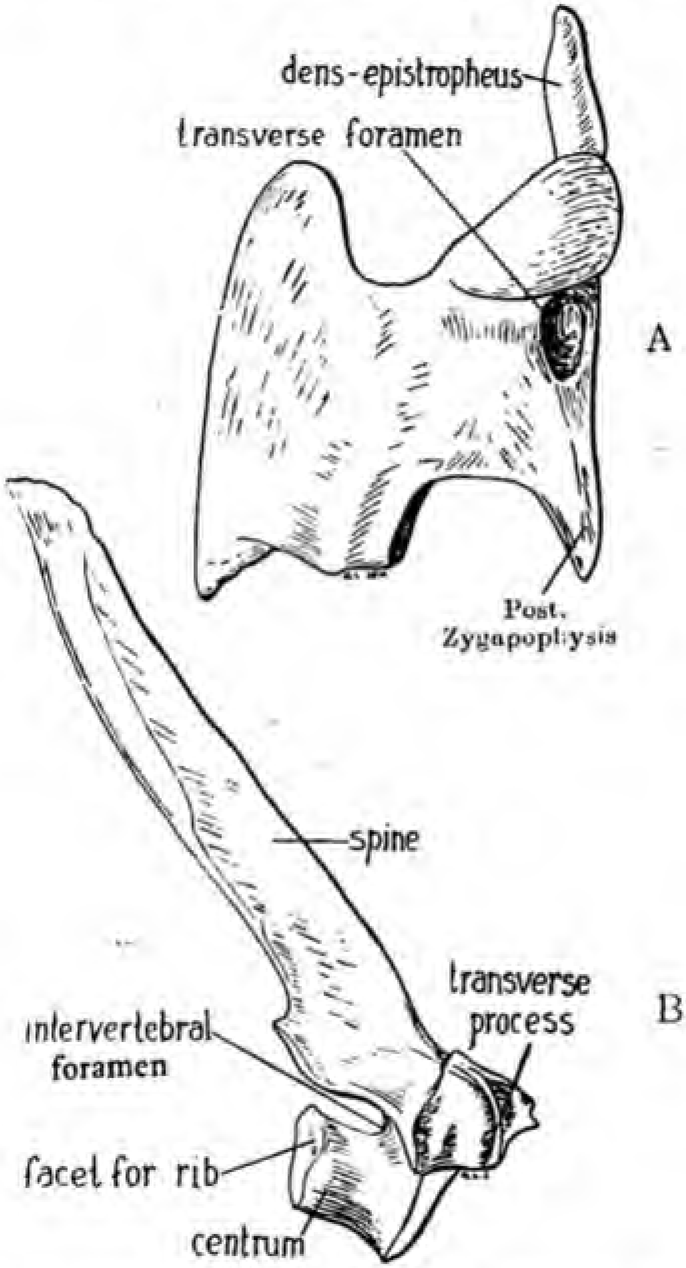


FIG. 410. A. The second vertebra of cat in lateral view. B. Thoracic vertebra of the rabbit in lateral view.

fused with the axis. It fits into the atlas below the spinal cord. The atlas permits the nodding movements of the head and the epistropheus acts as a pivot on which the atlas with the head turns sideways.

Regardless of the length of the neck, nearly all mammals have seven cervical vertebrae. The short-necked elephant and the long-necked giraffe have, for example, only seven vertebrae in the neck. The differences in the length of the neck thus arise from differences in the lengths of the cervical vertebrae. The only exceptions are sloths, which have six or nine and the Sirenians, which have six.

• **Thoracic vertebrae.** – The twelve thoracic vertebrae possess ***costal facets*** for the articulation of ribs: one on the centrum and the other on

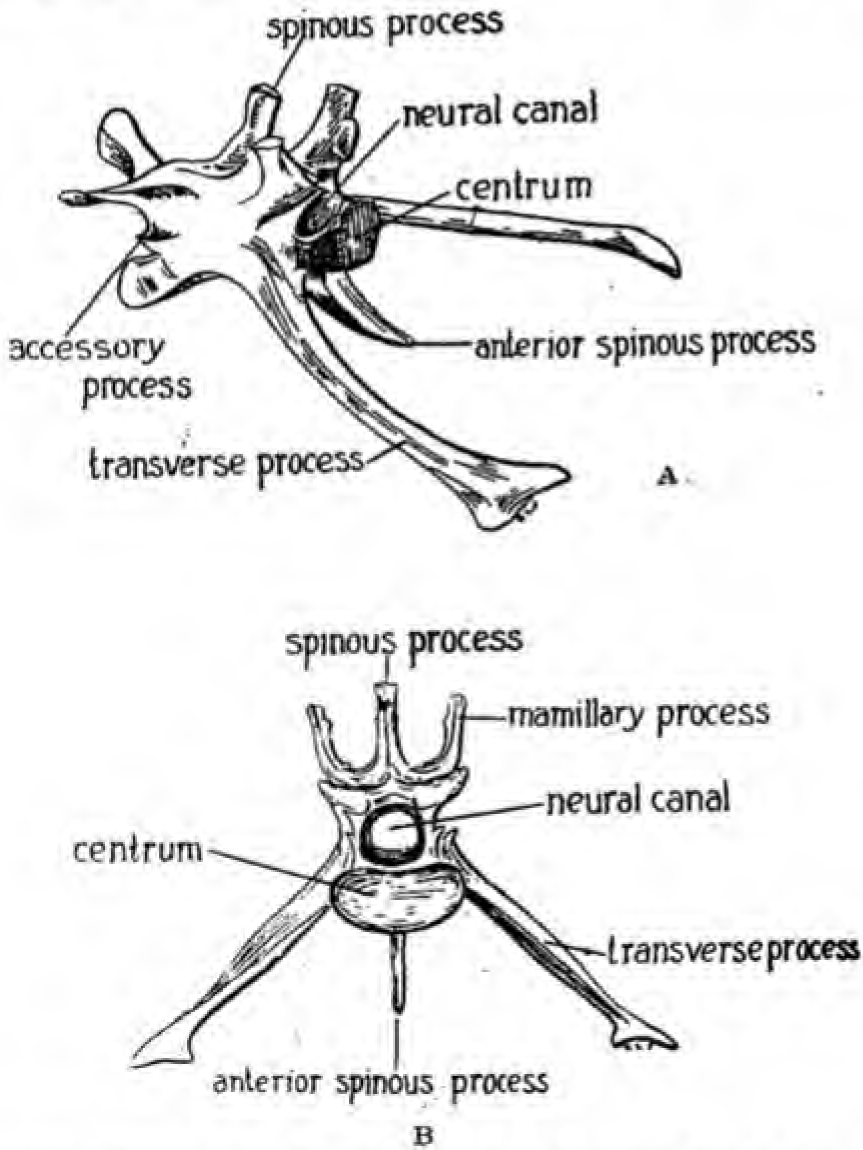
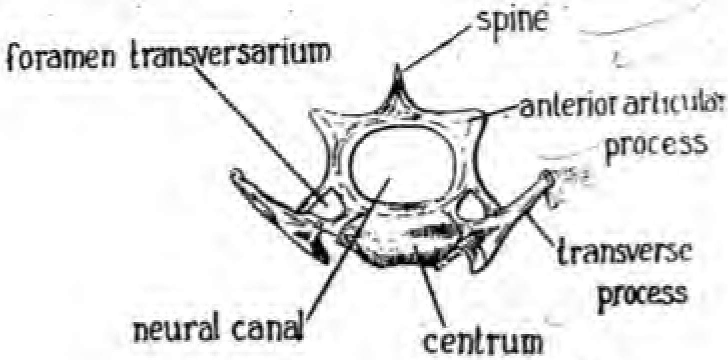


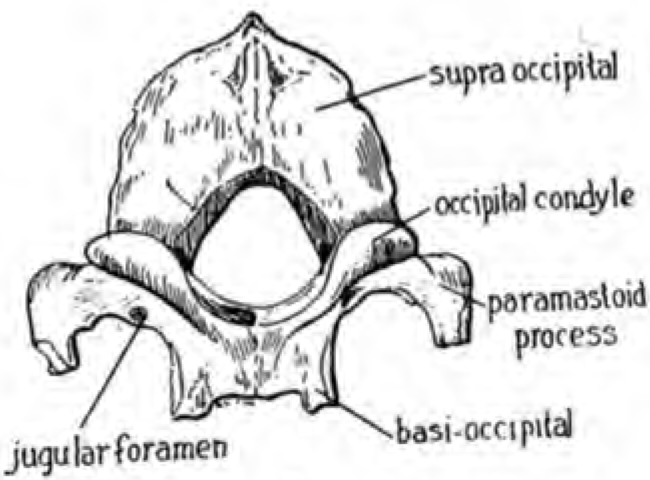
FIG. 411. Typical vertebra of mammal in A. lateral and B. anterior view.

the transverse process. The last two thoracic vertebrae have the costal facets wholly on the centra. In the remaining vertebrae the costal facet is formed by two ***demi facets***, one on the vertebra to which the rib belongs and the other on the preceding vertebra. The transverse processes of only first ten thoracic vertebrae have costal facets. The neural

spines are very long and increase in length to the third vertebra, then become shorter but wider. They are directed backward in the first ten vertebrae. The spinous process of the eleventh is almost vertical and that of the twelfth points forward.



A



B

FIG. 412. A. Cervical vertebra of mammal. B. Posterior view of the occipital region of the skull of rabbit.

Lumbar vertebrae.—The seven lumbar vertebrae are large. The broad neural spines are directed forward. The long transverse processes are directed forward, downward and outward. Their tips have the ***triangular plates*** that represent vestigial ribs. Stout upwardly directed ***mamillary processes*** bear the anterior articulating surfaces of the sacrum. The first three lumbar vertebrae bear each a median ventral ***anterior spinous process*** for the attachment of the diaphragm.

Sacral vertebrae.—The four sacral vertebrae are fused to form the ***os sacrum***. The hind part of the body is supported by the hindlegs

through the medium of the sacrum. The ***auricular surfaces*** antero-dorsally on the sacrum articulate with the pelvic girdle. Four pairs of ***anterior sacral foramina*** on the ventral surface lead into the interveterbral foramina. A pair of posterior ***sacral foramina*** opens dorsally in the line of junction of the first and second sacral vertebrae. Three ***median sacral foramina*** separate the neural arches of the fused vertebrae.

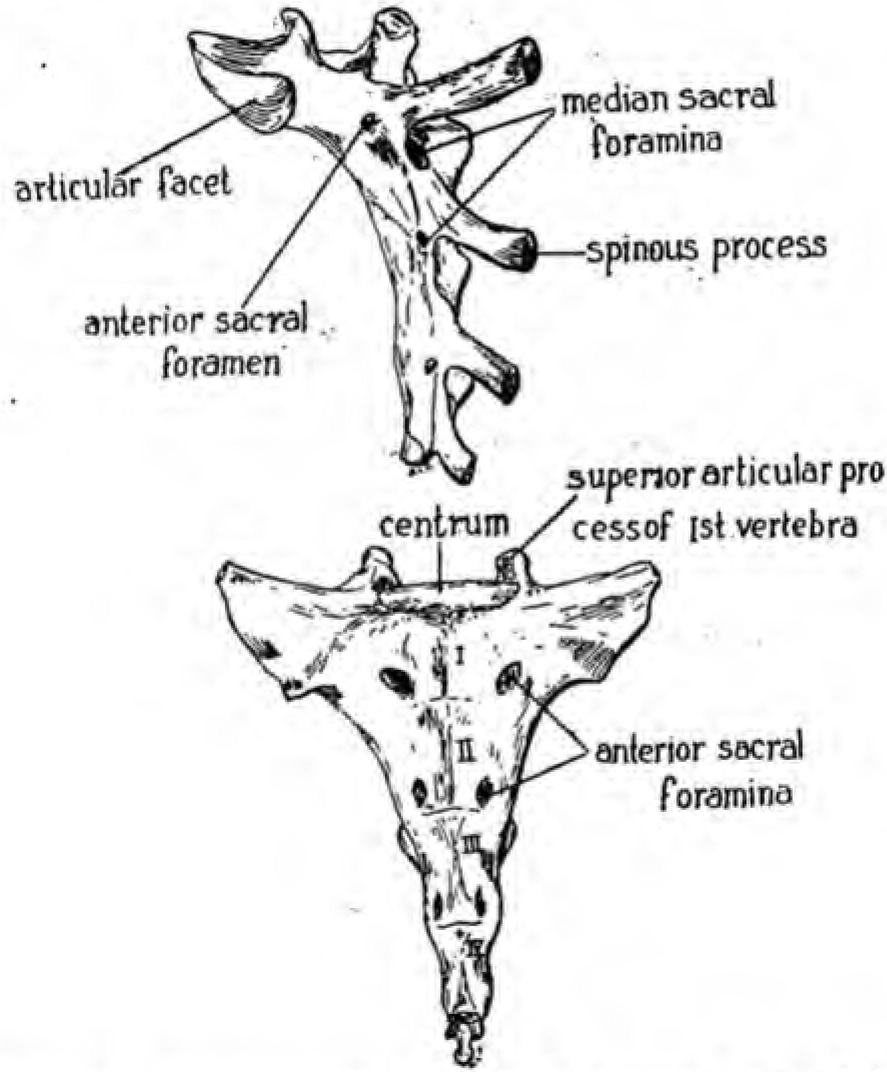


FIG. 413. Sacrum of rabbit in A. lateral view and B. ventral view.

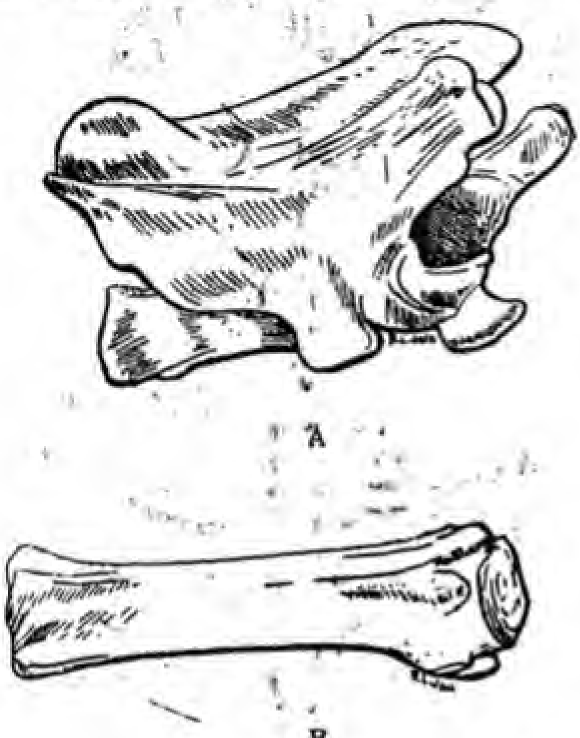
The ***caudal vertebrae*** are usually sixteen in number. The neural arches are complete in the first seven and the transverse processes are vestigial in all except the third. The terminal ones are reduced to mere cylinders that represent the centra.

The vertebral skeleton may be compared to a ***cantilever bridge*** or more appropriately to a girder supported on two pillars—the limbs—

nd loaded by the head at one end (Fig. 408). The high neural spines of the thoracic vertebrae give attachment to ligaments and tend o balance the weight of the head in front.

The Ribs

There are twelve ribs on each side. The ribs constitute a basket for the protection of the lungs and heart. They are so articulated with the vertebral column that they are capable of movement, resulting in an increase in the capacity of the thoracic cavity for respiration. Each rib comprises a dorsal ***costal bone*** and a ventral ***costal cartilage***.



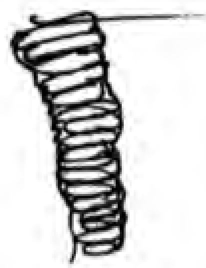


Fig. 414. Caudal vertebra of cat. A. From the base of tail. B. From near the tip of the tail.

The costal bone is articulated to the vertebra and points outward, downward and backward. The costal cartilages point inward, downward and forward. The first seven ribs are directly attached to the sternum; they are therefore called ***true*** or ***sternal ribs***. The last five ***false ribs*** are either indirectly attached or remain free as ***floating ribs***. They are thus seven true and five false ribs, of which three are floating ribs. The first rib is short. The succeeding ribs increase in length to the sixth but again grow shorter to twelfth. The ***head*** or ***capitulum*** of the costal bone articulates with the centrum and the tubercle with the transverse process.

STERNUM

The ***sternum*** is composed of six ***sternebrae***. The first, ***manubrium sterni***, articulates with the greatly reduced ***clavicle***. The next four constitute ***corpus sterni***. The sixth or the ***xiphoid*** process is an elongated bone with a thin broad cartilagenous plate behind.

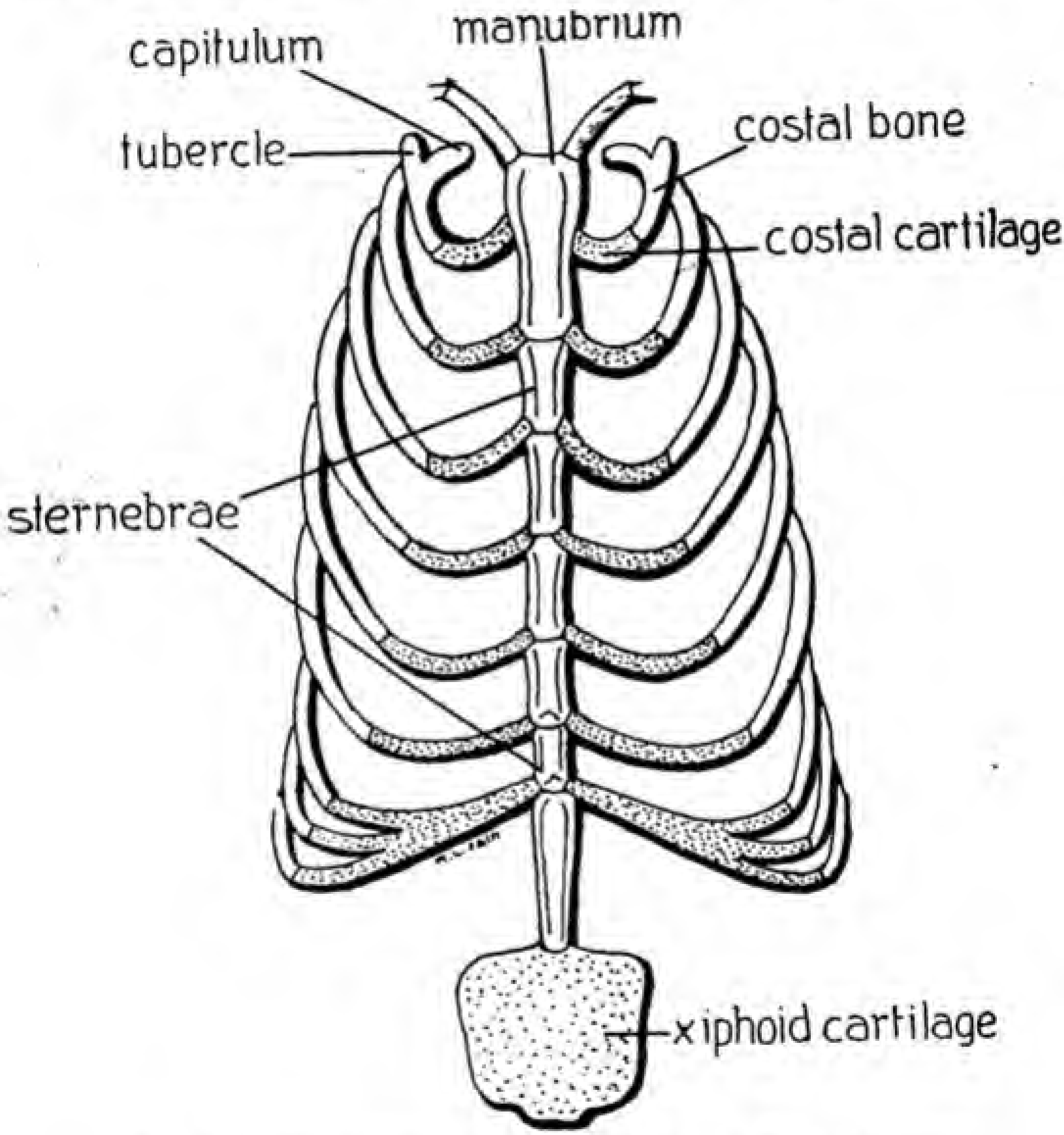


FIG. 415 The sternum and ribs of the rabbit in ventral view.

THE SKELETON OF THE HEAD

General features and regions of the skull.—The skull of the rabbit is completely ossified except for the cartilagenous internasal septum. There are fewer bones than in the frog and the bones are immovably jointed together by ***sutures*** in dovetail fashion The bones are, as in the frog, of

two kinds: ***cartilage bones*** and ***dermal bones***. There are also the same regions, viz. the cranium proper, the otic capsule, olfactory, the facial part, etc.

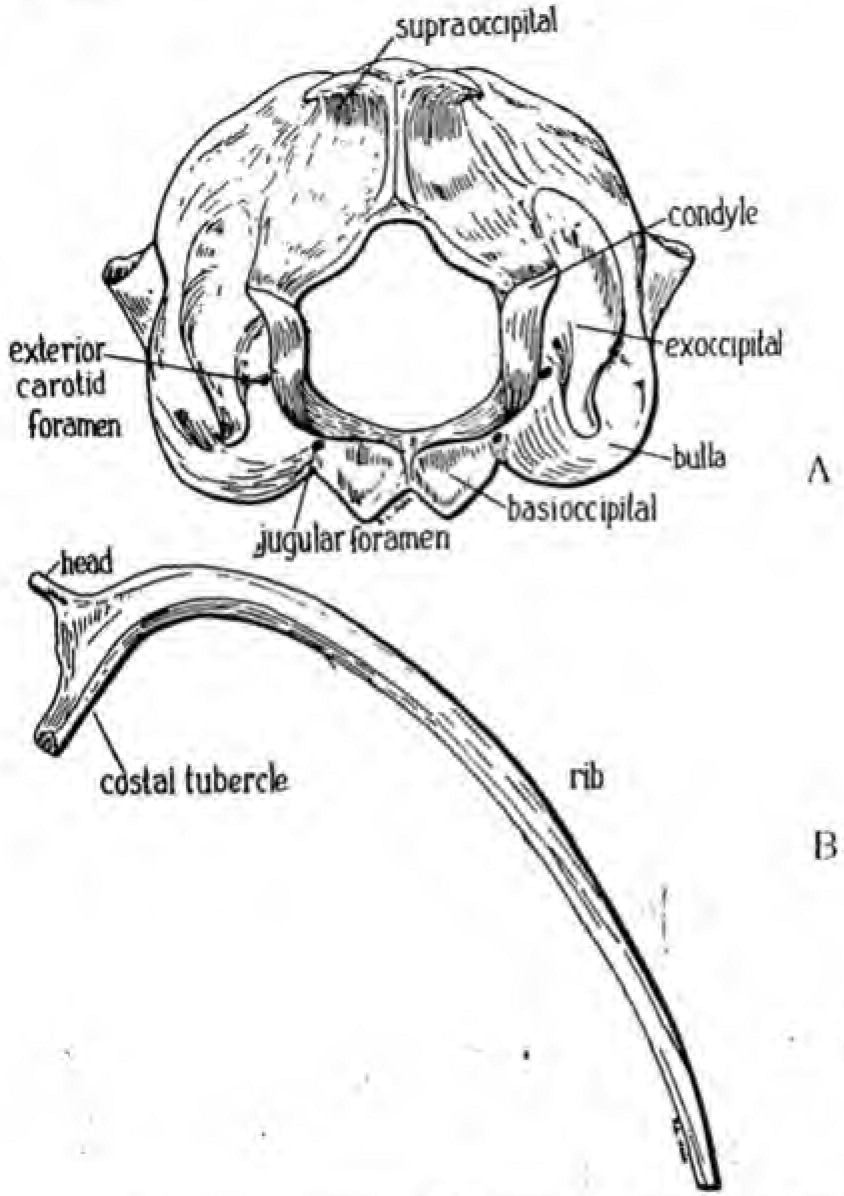


FIG. 416. A. Posterior view of the occipital region of the skull of dog. B. Rib of rabbit.

The facial region supports the nose and eyes. The two large external nares separated by the cartilagenous septum open at the end of the facial region. Behind the large orbits on the sides the ***temporal fossa*** is filled with muscles in life. The temporal fossa is bounded below by the ***zygomatic arch***, which is a distinguishing character of the skull of mammal.

The cranium is relatively large to accommodate a large brain. The floor of the cranium does not form the roof of the buccal cavity. There is a ***secondary palate*** (hard palate), so that the internal nostrils are displaced posteriorly (Fig. 417). The large ***foramen magnum*** is at the posterior end, with an ***occipital condyle*** on either side. Close to the condyles is the large hollow ***tympanic bulla,*** that encloses the middle ear.

The Cranium

A series of cartilage bones form the floor of the cranium and membrane bones complete its roof (Fig. 417).

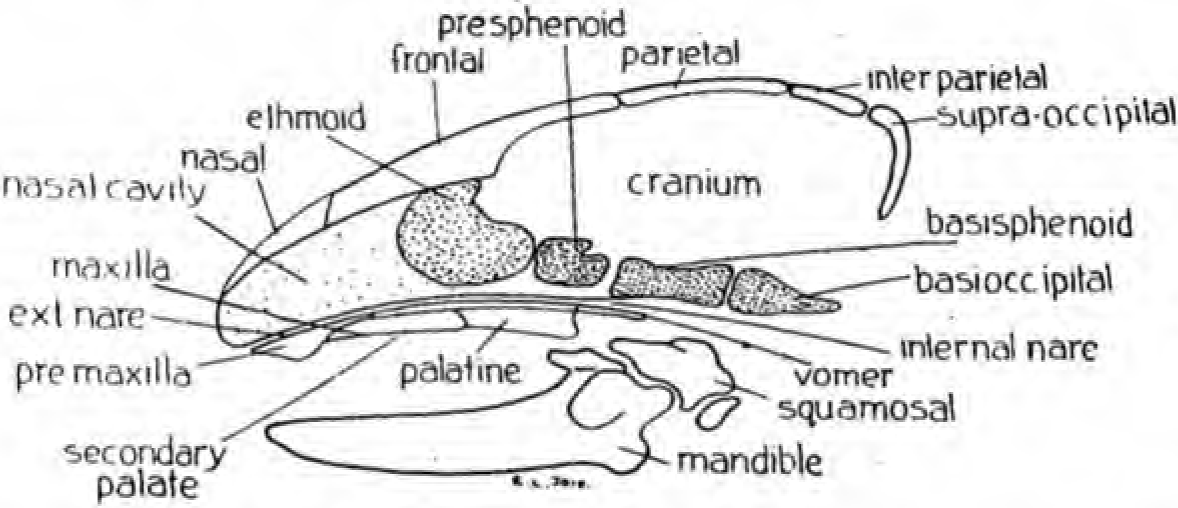


FIG. 417. Simplified diagram of the plan of a mammalian skull. The cartilage bones of the cranium are shaded.

Cartilage bones.—Commencing from behind, the cartilage bones of the cranium are 1. the ***occipitals,*** 2. the ***posterior sphenoidals,*** 3. the ***anterior sphenoidals*** and 4. the ***ethmoidals.***

The occipitalia comprise 1. the ***basioccipital,*** 2. the paired ***exoccipitals*** and 3. the ***supraoccipital.*** The four occipitals bound the foramen magnum. They are separate in the young animals, but fuse into a single bone in the adult. The basioccipital lies in front of the foramen magnum. The exoccipitals form the lateral boundaries of the foramen magnum and bear the occipital condyles. The supra-occipital is the dorsal part of the bone and bounds the foramen magnum above.

The posterior sphenoidals comprise a median unpaired ***basisphenoid,*** paired dorsolateral ***alisphenoids*** and paired ventral ***pterygoid processes*** (or "pterygoids"). The basisphenoid lies in front of the

basioccipital. The alisphenoid is partly lateral and partly dorso-ventral. It is convex externally and bounds the orbit.

The anterior sphenoidals consist of the median ***presphenoid*** and the paired lateral ***orbitosphenoids.*** The presphenoid is a narrow bone that lies in front of the basisphenoid. The orbitosphenoids are elongate plates in the ventral part of the orbit.

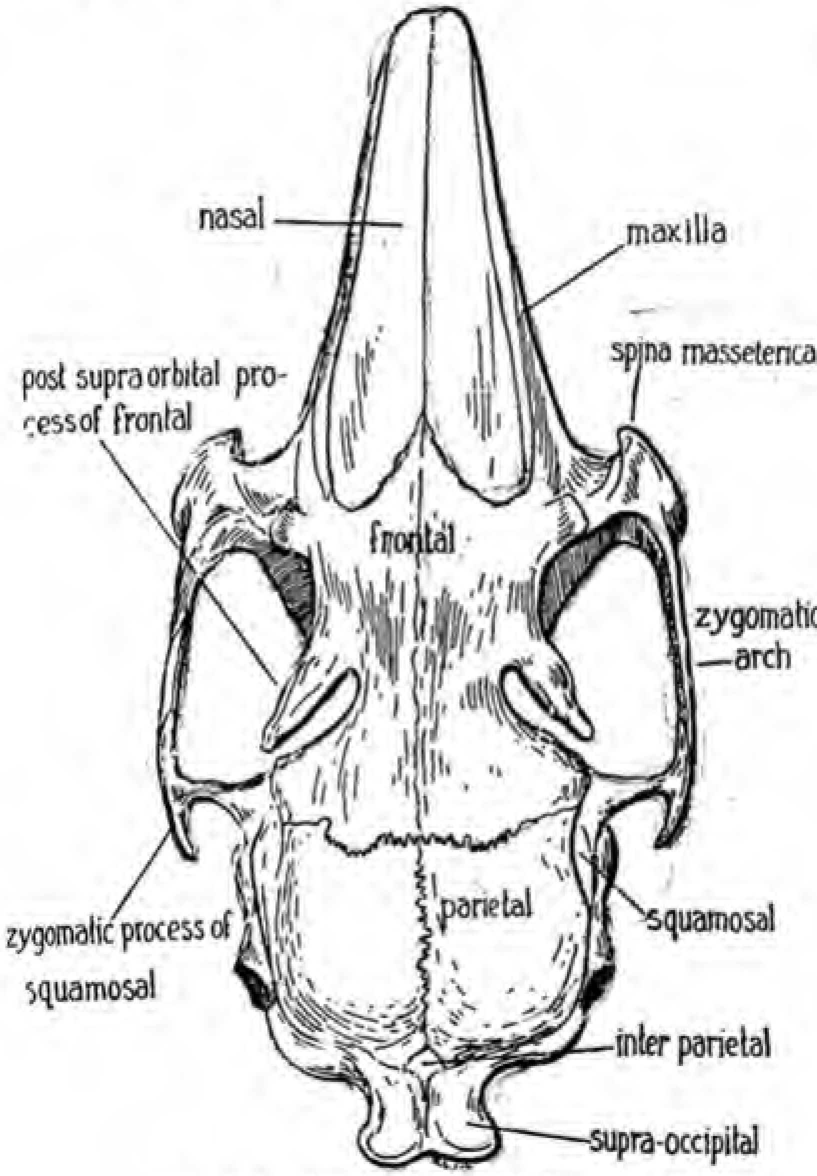


Fig. 418. Skull of rabbit in dorsal view.

The ethmoid bone includes the ***cribriform plate,*** the ***perpendicular plate*** and the ***ethmoidal labyrinth.*** The cribriform plate separates the cranial cavity from the nasal cavity in front. It derives its name from its sieve-like perforations. The branches of the olfactory nerve pass out of the cranium through these holes. The perpendicular

plate separates the two nasal cavities. In life, it is continued anteriorly by cartilage up to the external nares. They constitute together the ***internasal septum*** (mesethmoid) of the nose. The ethmoid labyrinth or ***ethmoturbinal*** lies just in the front of cribriform plate. It is composed of scrolls of thin bone that increase the olfactory and respiratory surfaces of the nose.

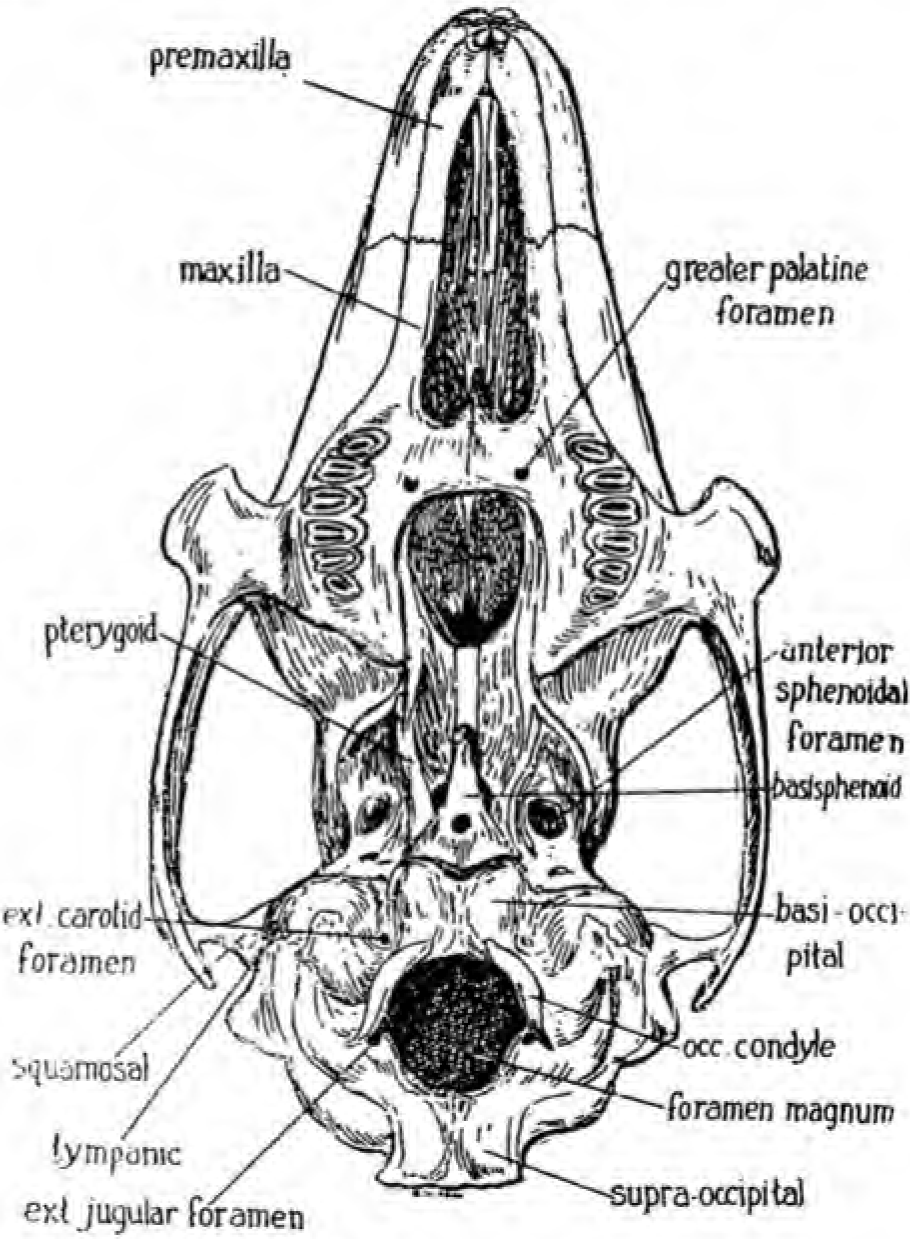


FIG. 419. Skull of rabbit in ventral view.

The ***membrane bones*** that compose the cranial roof are 1. the *upper part* of the ***supraoccipital***, 2. the ***interparietal***, 3. the paired ***parietals*** and 4. the paired ***frontals***.

The supraoccipital that bounds the foramen magnum is ossified in cartilage near the foramen but further above ossified in membrane. The ***interparietal*** is a small unpaired bone lying between the supra-occipital and parietals. The two ***parietals*** cover a large area. The ***frontals*** are paired bones that lie immediately in front of the parietals. They form the anterior part of the cranial roof, a large part of its side in front and part of the orbit. Each consists of a ***frontal portion*** proper and an ***orbital portion***. The two portions meet at the ***supraorbital border*** overhanging the eye. This is produced in front and behind as the ***anterior*** and ***posterior supraorbital processes*** of the frontal. The orbital portion of the frontal forms a considerable part of the orbital wall. Anteriorly it is in contact with the ***lachrymal*** bone.

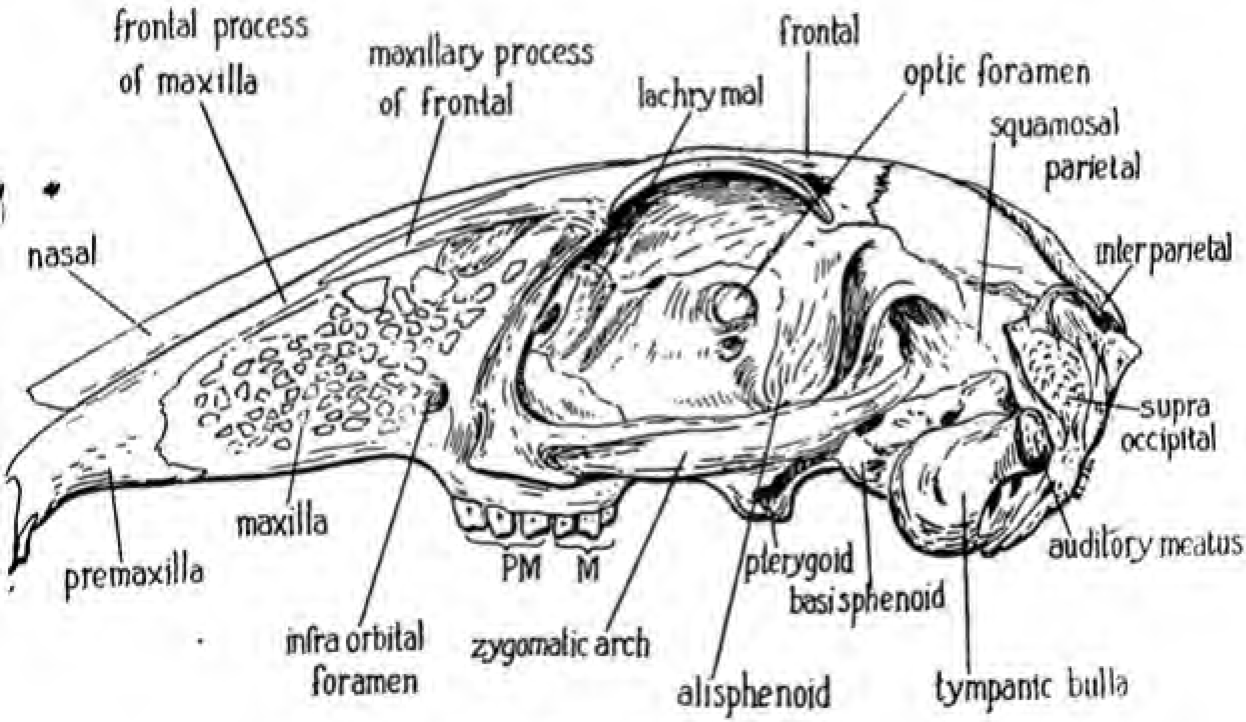


FIG. 420. Skull of rabbit in lateral view.

The remaining part of the cranial wall is completed by 1. ***squamosal*** and 2. ***petrotympanic*** bones. The squamosal is a rectangular bone that forms a part of the lateral wall of the cranium. It articulates in front with the orbitosphenoid and orbital portion of the frontal, behind with the supraoccipital and petrotympanic and ventrally with the alisphenoid. It bears the ***zygomatic process*** of the squamosal. This process bears ventrally the ***mandibular fossa*** for the reception of the lower jaw. The petrotympanic is an oblong

bone that lies in the lateral wall of the cranium between the occipital and posterior sphenoidals. It is composed of the ***periotic*** and the ***tymapnic*** bones. It is indicated externally by the ***tympanic bulla*** and the ***external auditory meatus.*** It articulates anteriorly with the alisphenoid and the squamosal and posteriorly with the exoccipital. The petrotympanic comprises a ***petrous*** and a ***mastoid*** portion. The petrous portion contains internal ear. The mastoid forms the ***mastoid process*** between the exoccipitals and the auditory meatus.

THE FACIAL PART

The facial part of the skull is composed largely of membrane bones of upper jaw, the palate and the mandible. It also encloses the olfactory region of the cranium.

A pair of ***nasals*** roof the nasal cavity. These lie behind the external nares and articulate behind with the frontals. The nasal bone of each side meets together by a straight suture in the middle. Below this suture lies the internasal septum. The internal surface bears the ***nasoturbinal scrolls*** similar to the ethmoid labyrinth.

The bones of the upper jaw and the palate.—The upper jaw is composed of two cartilage bones on each side: the ***premaxilla*** and ***maxilla***. These two together form the greater part of the facial region of the skull. The premaxilla is ventral to the external nares and bears teeth. The maxilla forms the lateral wall of the face and also bears teeth. In the rabbit it is ***fenestrated*** i.e., exhibits a network of perforations. The ***zygomatic process*** of the maxilla is fused with the zygomatic arch. The ***palatine process*** of the maxilla together with the premaxilla constitute the anterior part of the hard palate. The ***orbital process*** of maxilla forms part of the wall of the orbit. The maxilla meets the frontal above by the ***frontal process***.

The palate or the roof of the buccal cavity is therefore *not* the base of the cranium (Fig. 417). There is a secondary or ***false*** palate (hard palate). This is formed in front by the palatine processes of the premaxilla and maxilla. Posteriorly the palate is formed by the ***palatine bone.*** The ***vomer*** is a vertical plate of bone, the posterior end of which is visible behind the palatine.

The lower jaw.—The ***mandible*** or the lower jaw bone is composed of two portions—the right and the left halves—united in front by the ***mandibular symphysis***. Each half consists of a horizontal body and a vertical ***mandibular ramus.*** The posteroventral part

of the ramus forms the ***angle.*** The ***condylar process*** articulates with the mandibular fossa of the squamosal below the zygomatic arch. There is *no* quadrate between the mandible and the skull as in the frog. Nerves and artery enter the mandible by the ***mandibular foramen*** and leave by the ***mental foramen.***

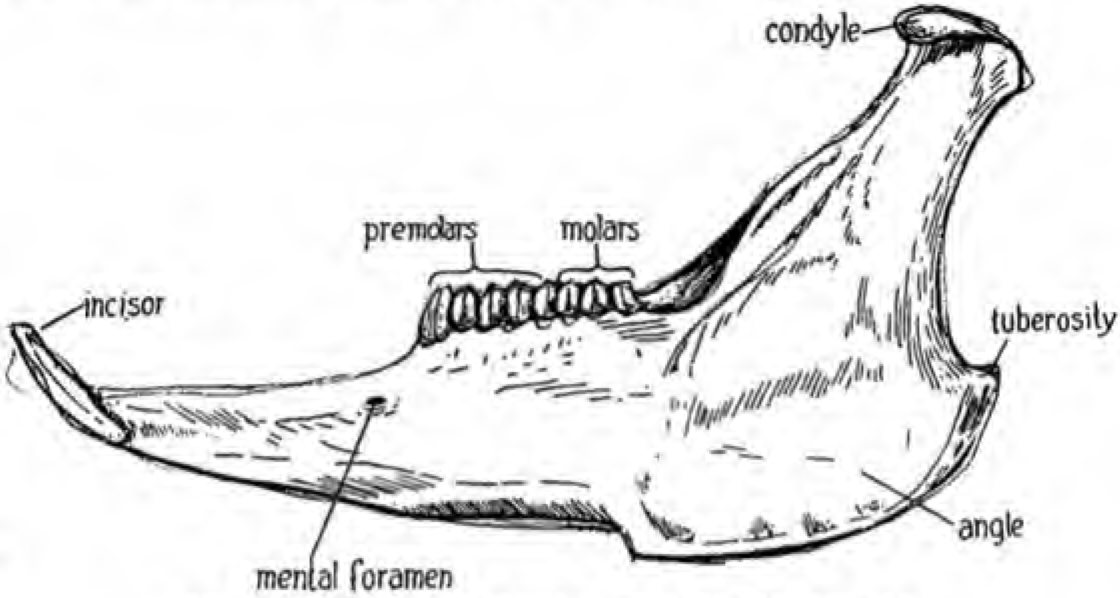


FIG. 421. Mandible of rabbit in lateral view from outside.

THE EAR BONES

The tympanic bulla is closely applied to the outer surface of the ***petromastoid*** bone, a part of the cranial wall that encloses the internal ear. It thus encloses a ***tympanic cavity*** or the ***middle ear.*** This cavity contains a chain of three deliacte ***auditory ossicles*** or the ear bones. These bones transmit the vibrations of the outer ear drum to the inner drum.

The chain of three ossicles comprises : 1. the ***malleus,*** 2. the ***incus*** and 3. the ***stapes.*** The malleus is a hammer-shaped bone with its ***head*** partly concealed in the external bony auditory meatus. The handle or ***manubrium mallei*** is a stout vertical process of the malleus that lies in contact with the tympanic membrane The malleus is really the reduced ***articular bone*** of the mandible that has lost its connection with the lower jaw. The ***incus*** is directly articulated with the malleus. It bears a downwardly-directed long limb which articulates with the head of the stapes. The incus represents the very much reduced and modified ***quadrate*** of the upper jaw of the frog. The ***stapes*** is a stirrup-shaped bone set transversely in the ear cavity. Its head articulates with the incus and its base plugs

the ***fenestra ovalis*** (also called vestibular fenestra) that opens into the vestibule containing the internal ear. The stapes is a remnant of the ***columella auris*** of the frog.

Dog Skull

On account of its larger size, the skull of the dog is usually substituted for that of the rabbit.

The dog skull contains essentially the same bones as in the rabbit. The cranial floor is formed by 1. basioccipital, 2. basisphenoid, 3. presphenoid and 4. ethmoid. On either side of these lie respectively the exoccipitals, alisphenoids and orbitosphenoids. The supraoccipital lies above the foramen magnum. Interparietal, parietals, frontals and nasals form the roof of the skull. The premaxilla and maxilla constitute the upper jaw. The palate is formed by the palatine processes of the premaxilla and maxilla, and the palatine. The zygomatic arch bridges the maxilla and squamosal.

The dog skull however differs from that of the rabbit in the following essential features :

1. The jaws are elongated to accommodate the large number of teeth.
2. The postorbital processes are short.
3. The tymapnic bulla and the paraoccipital processes are united.
4. The dentition is I 3/3, C 1/1, PM 4/4 and M 2/2 or 3. The upper incisors are pointed. The canines are long and adapted for piercing and tearing flesh. The largest of the teeth – the first molar is modified as ***carnassial*** (Fig. 426) tooth for tearing flesh and crushing bone.
5. In the temporal fossa there is a bony channel—the ***alisphenoid canal***, through which runs a branch of the carotid atrery.
6. The mandibular condyle is an elongate transverse cylindrical structure.

Skull Foramina

The skull is pierced by a number of apertures or ***foramina*** (singular : foramen) for the passage of nerves and blood vessels.

1. ***Infroarbital foramen*** is a large opening in the maxilla at the beginning of the zygomatic arch. Branches of the trigeminal nerve and blood vessels pass through it.

2. ***Lachrymal foramen*** is at the end of the lachrymal bone and is connected by the ***nasolachrymal canal*** with the nasal cavity. It serves for the passage of the tear.

3. ***Sphenopalatine foramen*** lies in the orbital part of the palatine bone, behind the lachrymal. Branches of the trigeminal nerve pass through it.

4. ***Posterior palatine foramen*** is ventral to the sphenopalatine and communicates by a canal into the palatine process of maxilla to open at the ***anterior palatine foramen***. Branches of the trigeminal pass through it.

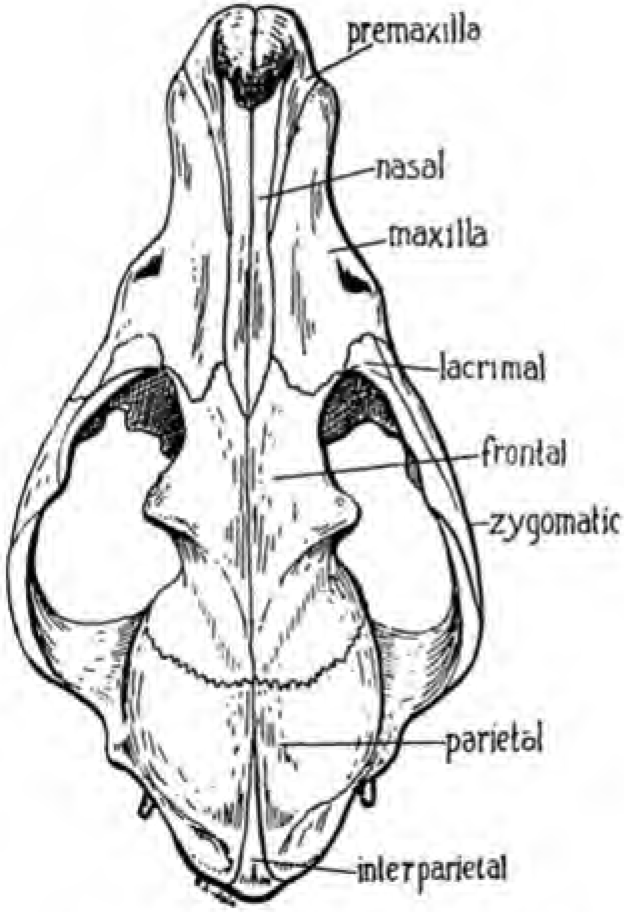


FIG. 422. Skull of dog in dorsal view.

5. ***Optic foramen*** is in the orbitosphenoid for the passage of the optic nerve.

6. ***Sphenoidal foramen*** lies between the orbitosphenoid and the alisphenoid. The oculomotor, trochlear, abducens and branches of the trigeminal nerves pass through it.

7. ***Anterior pterygoid foramen*** is the third foramen in the alisphenoid in the dog skull and serves for the exit of the external carotid artery.

8. ***Formen rotundum*** pierces the sphenoid bone between the alisphenoid and the basisphenoid. Branches of the trigeminal nerve pass through it.

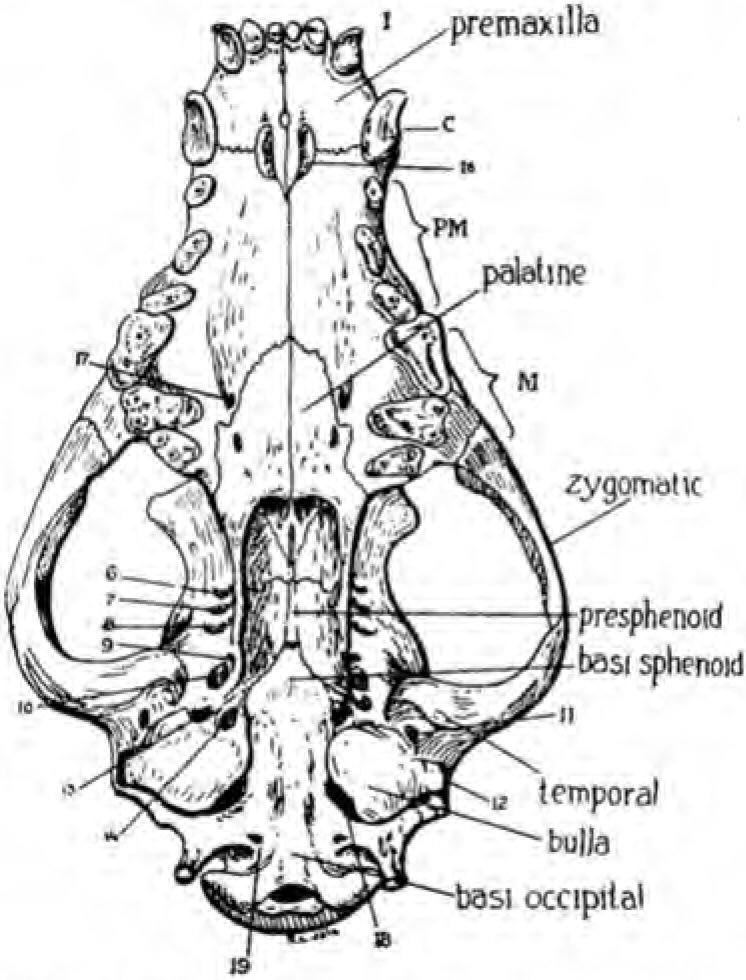


FIG. 423 Skull of dog in ventral view. Foramina: 6. optic foramen, 7. sphenoidal foramen, 8. foramen rotundum, 9. posterior pterygoid foramen, 10. foramen ovale, 11. posterior glenoid foramen, 12. external auditory meatus, 13. Eustachian foramen, 14. carotid foramen, 16. incisive foramen, 17. anterior palatine foramen, 18. foramen posterior lacerum, 19. hypoglossal foramen. Dentition: I. incisor, C. canine, PM. premolar, M. molar.

9. ***Posterior pterygoid foramen*** is confluent with foramen ovale.

10. ***Foramen ovale*** is large in the dog and serves for the passage of the mandibular branch of the trigeminal nerve.

11. ***Posterior glenoid foramen*** is a large aperture, for the passage of a vein, by the side of the tympanic bulla and behind the glenoid process.

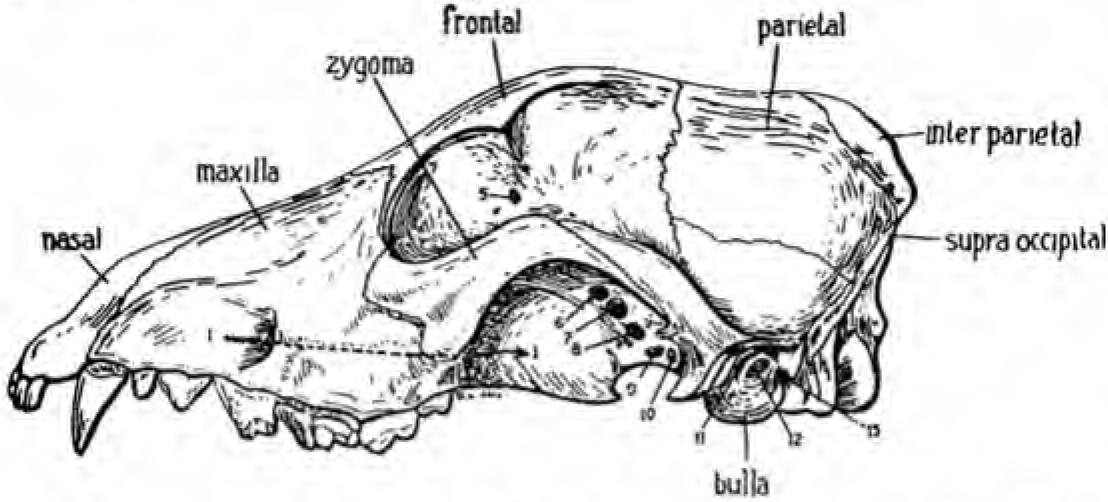


Fig 424. Skull of dog in lateral view. Foramina: 1. infraorbital canal, 5. ethmoid foramen, 6. optic foramen, 7. spenoidal foramen, 8. anterior pterygoid foramen, 9. posterior pterygoid foramen, 10. foramen ovale, 11. posterior glenoid foramen, 12. external auditory meatus, 13. stylomastoid foramen.

12. ***Carotid foramen*** opens in front of the tymapnic bulla and mesial to the opening of the Eustachian tube.

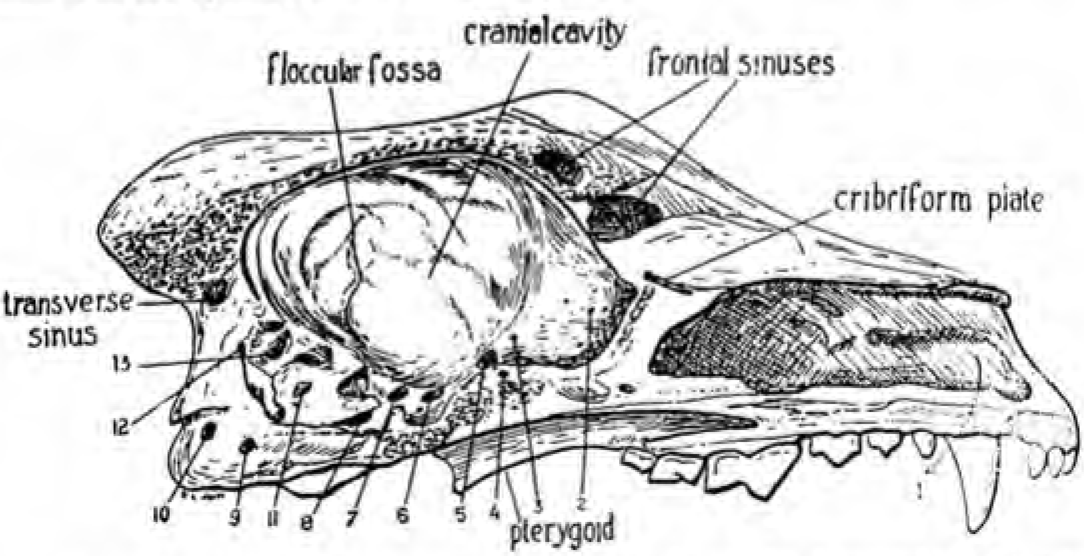


Fig. 425. Skull of dog cut along the median longitudinal line and viewed from inside. Foramina: 1. incisive foramen, 2. ethmoid foramen, 3. optic foramen, 4. sphenoidal foramen, 5. foramen rotundum, 6. foramen ovale, 7. carotid foramen, 8. internal auditory meatus, 9 hypoglossal foramen, 10. condylar foramen.

13. ***Stylomastoid foramen*** opens at the inner posterior side of the bulla or in front of the mastoid process in the rabbit. It serves for the exit of the seventh cranial (facial) nerve.

14. ***Incisive foramina*** (anterior palatine foramina) open at the anterior end of the ventral side of the maxilla and are bounded by premaxilla and maxilla. They connect the roof of the mouth with the nasal cavities but in life do not open into the buccal cavity. The nasopalatine branch of the trigeminal nerve makes its exit through it.

15. ***Anterior (greater) palatine foramen*** opens on the roof of the mouth on either side of the median line, between the maxilla and palatine It serves for the entry of an artery to the floor of the nasal cavity.

16. ***Foramen posterior lacerum*** is a large irregular aperture on the posterior face of the tympanic bulla in the dog skull. The internal carotid artery enters the cranium and a large vein leaves it by this foramen.

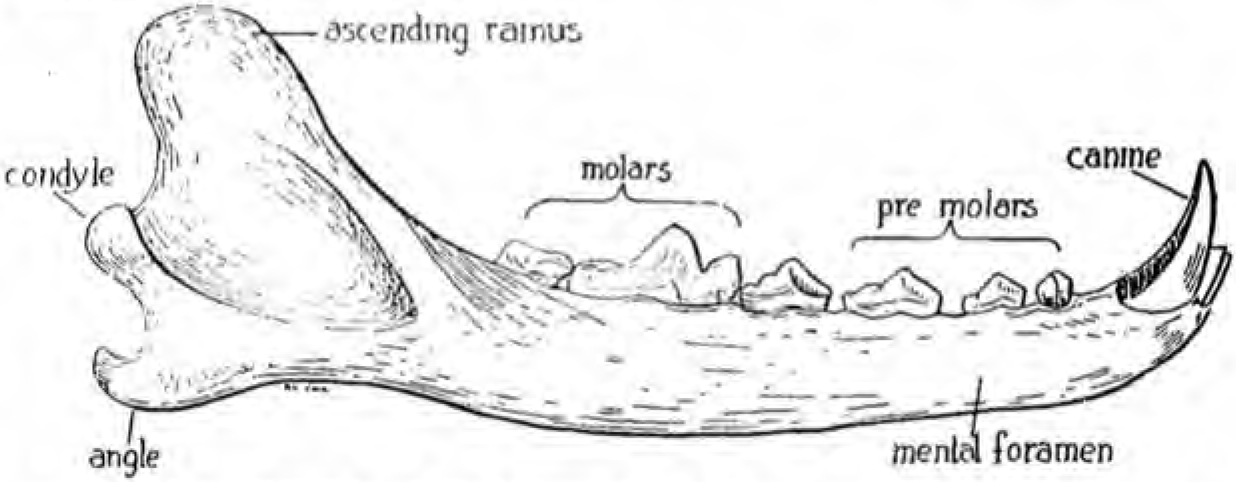


FIG. 426. Mandible of dog in lateral view from outside. The first molar, the largest, is the carnassial tooth.

17. ***Hypoglossal foramen*** lies behind the foregoing and serves for the exit of the hypoglossal nerve.

18. ***Condylar foramen*** opens on the lateral wall of the foramen magnum.

19. ***Mandibular foramen*** opens on the inner side of the mandible in front of the mandibular condyle. It serves for the entry of the mandibular branch of the trigeminal and blood vessels to the mandible and teeth. The mandibular nerve that enters here sends out a branch—the *mental nerve* through the mental foramen.

20. ***Mental foramen*** opens on the outside of the mandible and serves for the exit of the mental nerve.

Hyoid apparatus.—The hyoid apparatus comprises the hyoid bone in front of the larynx. It is connected with the thyroid cartilage by a ligament. Laterally it is articulated to the ***lesser cornu*** and ***greater cornu***.

Table of Bones of the Mammalian Skull

Region of skull	Cartilage bone	Membrane bone
Floor	Basioccipital Basisphenoid Presphenoid Pterygoid	Vomer
False palate	Palatines	Maxilla
Roof	Supraoccipital	Parietals Frontals Nasals
Side wall	Periotic Alisphenoid Orbitosphenoid	Squamosal Lachrymal Tympanic
Upper jaw		Premaxilla Maxilla
Lower jaw		Dentary
Zygomatic arch		Jugal Squamosal
Ear ossicles	Stapes Incus Malleus	

Table of Foramina of the Mammalian Skull

Foramen	Bones	Structure transmitted
1. Infraorbital canal	Maxilla	Maxillary nerve of V
2. Lachrymal	Lachrymal	Naso-lachrymal duct
3. Sphenopalatine	Palatine	Sphenopalatine nerve and artery
4. Posterior palatine	Palatine	Palatine nerve and artery
5. Ethmoid	Frontal	Ethmoid branch of ophthalmic
6. Optic	Orbitosphenoid	Optic tract
7. Sphenoidal	Between orbito-, ali- and basisphenoid	III, IV, VI and ophthalmic nerves of V
8. Anterior pterygoid	Ali- and basisphenoid	Maxillary nerve of V
9. Rotundum	Basisphenoid	Maxillary nerve of V
10. Posterior pterygoid	Alisphenoid	External carotid
11. Ovale	Alisphenoid	Mandibular nerve of V
12. Posterior glenoid	Squamous portion of temporal	Vein from the transverse sinus of meninges
13. External auditory meatus	Bulla of temporal	Inlet to tympanum of ear
14. Internal auditory meatus	Petrous portion of temporal	VII and VIII nerves
15. Eustachian	Between bulla and alisphenoid	Tuba auditiva
16. Carotid	Through temporal ventral to bulla	Loop of the internal carotid extends into this foramen
17. Stylomastoid	Between temporal and basioccipital	Exit of VII nerve

Foramen	Bones	Structure transmitted
18. Incisive	Between maxilla and premaxilla	Connects with Jacobson's organ, transmits nasopalatine nerve, Stenson's duct and palatine nerve
19. Anterior palatine	Between maxilla and palatine	Palatine nerve
20. Posterior lacerum	Between bulla and basioccipital	IX, X and XI nerves, internal carotid and veins from the meningeal sinus
21. Hypoglossal	Occipital bone	XII nerve
22. Foramen magnum	Occipital bone	Spinal cord, veins and arteries from cranium
23. Condylar canal	Occipital bone	Condylar vein from meninges
24. Mandibular	Mandible	Entry of mandibular nerve of V and blood vessels
25. Mental	Mandible	Exit of Mandibular nerve of V to chin and blood vessels

Comparison with Frog Skull

1. The rabbit skull is more completely ossified than the frog skull. The only cartilagenous part is the mesethmoid that forms the internasal septum.

2. The cranial portion of the rabbit skull is proportionately larger than in the frog skull.

3. In the rabbit the occipital region ossifies in four centres to give rise to supraoccipital, two exoccipitals and basioccipital. In the frog only the exoccipitals are found.

4. Parasphenoid is absent in the rabbit skull.

5. In the frog the cranial floor itself forms the palate—the roof of the buccal cavity, but in the rabbit there is secondary palate formed by premaxilla, maxilla and palatine.

6. In the frog the internal nostrils open anteriorly in the buccal cavity but in the rabbit the formation of the secondary palate pushes this opening far backwards.

7. The zygomatic arch is an important element in the rabbit skull not represented in the frog.

8. The lower jaw is articulated to the skull by the quadrate in the frog. The quadrate having receded into the internal ear as the incus, the lower jaw of the rabbit is articulated to the squamosal.

9. The tympanic bulla of the rabbit is another character not met with in the frog.

10. In the frog vomers bear the teeth but not in rabbit.

The Appendicular Skeleton

The appendicular skeleton of the rabbit comprises the two limbs and the girdles by which the limbs are attached to the axial skeleton. The ***pectoral girdle*** attaches the fore limbs and the ***pelvic girdle*** attaches the hind limbs.

Pectoral Girdle

The pectoral girdle is light and is attached to the vertebral column only by muscles and by the ***sternoclavicular ligament***. It does not directly articulate with the vertebral column. It comprises only two bones : the ***scapula*** and the ***clavicle***.

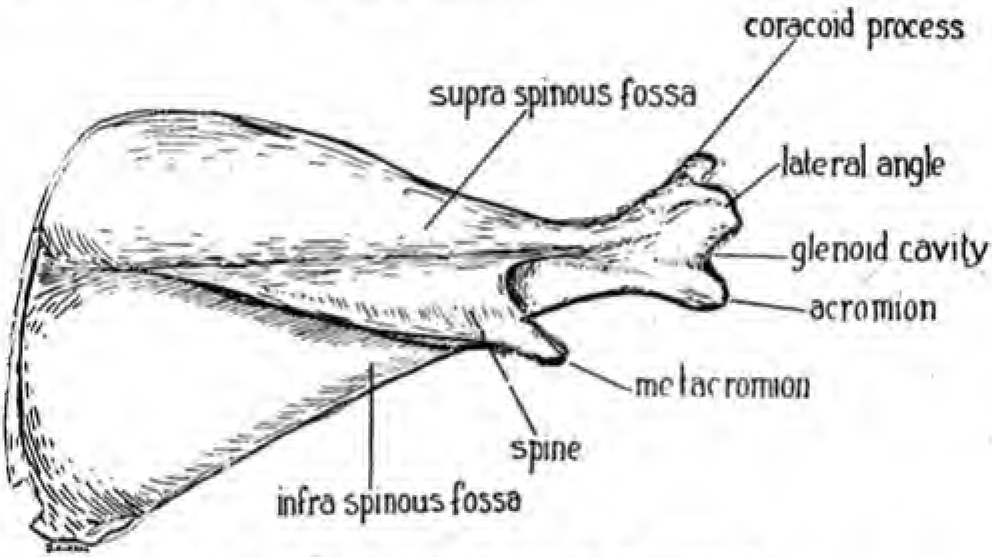


Fig. 427. Scapula of rabbit in dorsal view.

The scapula. – The scapula is a subtriangular plate that lies antero-laterally on the dorsal surface of the thorax. Its apex is directed below and in front. Its three borders are : *superior border* that is turned towards the head, the *vertebral border* towards the vertebral column and the *axillary border* towards the armpit. The ***scapular spine*** is a stout bony plate on its dorsal surface extending to about two-thirds the scapula. The scapular spine ends ventrally in the ***acromion*** process. The acromion bears behind a long ***metacromion***. In front of the scapular spine is the ***supraspinous fossa*** and behind lies the ***infraspinous fossa***. The ***subscapular fossa*** is on the ventral surface of the scapula. The scapular apex is expanded and bears the ***glenoid cavity***, a concave depression that receives the head of the humerus. The ***coracoid process*** overhangs the glenoid cavity in front. The suprascapula is represented by a narrow cartilage on the vertebral border and is lost in the dried skeleton.

The clavicle.—The clavicle is reduced to a slender curved bone rod, between the manubrium sterni and the head of the humerus.

Pelvic Girdle

The pelvic girdle is more solidly built than the pectoral girdle. It comprises the ***ossa innominata*** or ***coxal bones*** and is directly articulated to the sacral vertebra. The ***coxal bone*** is roughly a three-rayed bone. The hind rays are united but enclose a large ***obturator foramen***. The coxal bones of the two sides are united ventrally at the ***pubic symphysis*** or ***pelvic symphysis***. Each coxal bone comprises the ***ilium, ischium*** and ***pubis***, that meet at the ***acetabulum***, the concavity for the head of the femur. The acetabulum itself is formed only of ilium and ischium. The ilium is the anterior and dorsal part of the coxal bone. The ischium extends behind the acetabulum. The pubis lies below the acetabulum.

Comparision with the Frog

The pectoral girdle of the rabbit is relatively small and is completely ossified, except for the vestigial cartilagenous suprascapula. There is no calcified cartilage as in the frog. The suprascapula is not so large as in the frog and is lost in the dried skeleton. The coracoid is reduced to a small tubercle and fused with the scapula to form the coracoid process. The clavicle is also imperfectly developed.

In the pelvic girdle the ilium is relatively short. The three bones do not take part in the formation of the acetabulum. In the frog the coxal bones of two sides are completely united together behind. In the rabbit the union of the coxal bones of the two sides is only at the pubic symphysis, the ilial and ischial elements of the two sides do not meet.

The Fore Limb

The skeleton of the fore limb comprises a proximal, a middle and a distal segment. The proximal segment consists of a single bone—the ***humerus***. The humerus consists of a ***shaft*** and ***proximal*** and ***distal extremities***. The head of the humerus at the proximal extremity articulates with the glenoid cavity of the scapula. The articulation is a typical ball-and-socket joint. The ***lesser tubercle*** or ***medial tuberosity*** is front of the head. The ***greater tubercle*** is separated from the lesser tubercle by a groove on the anterior surface. The distal extremity forms the ***trochlea humeri*** or the pully-like articu-

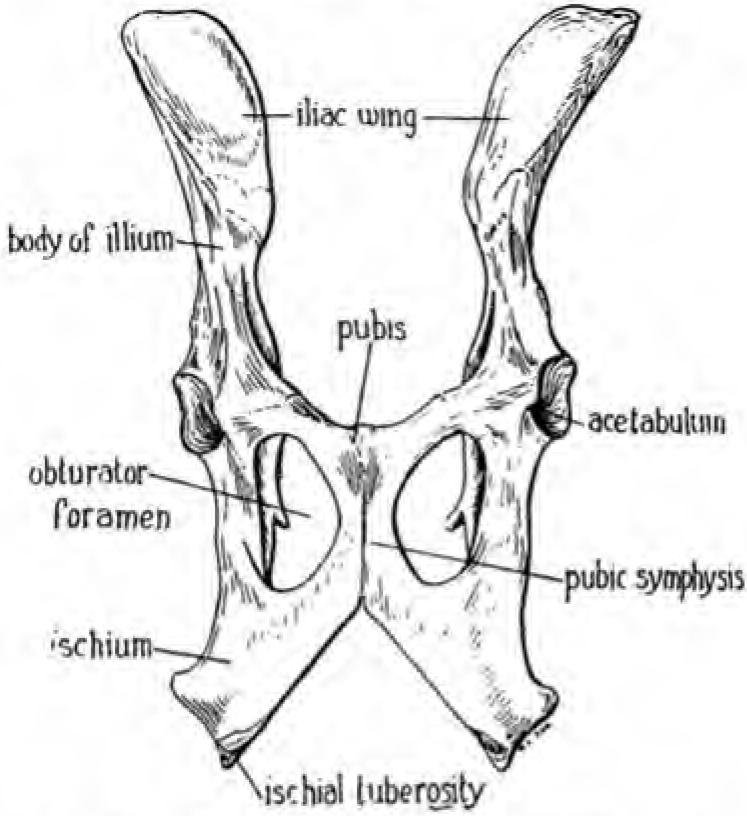


FIG. 428. The pelvic girdle of rabbit in ventral view.

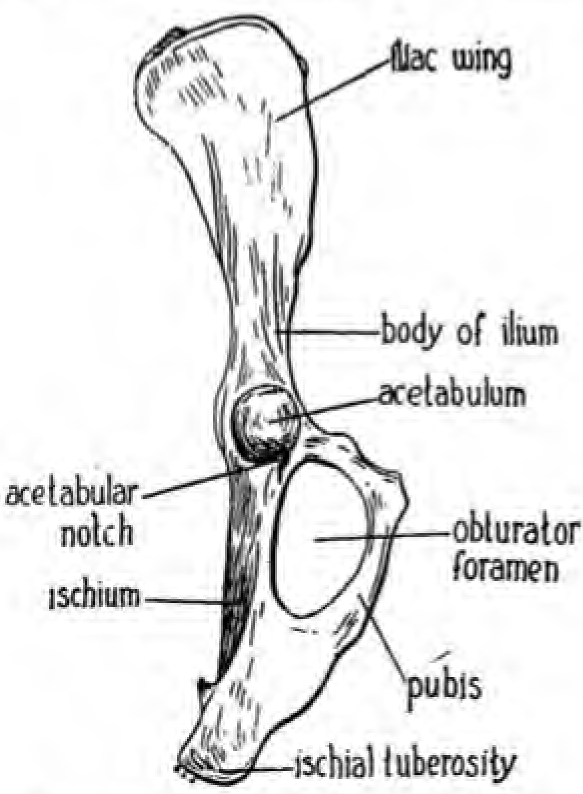


FIG. 429. The coxal bone of rabbit in lateral view from outside.

lating surface The middle segment comprises two bones: the ***radius*** and ***ulna***. The radius is the shorter of the two. The head of the radius is immovably articulated with the ulna. Distally it bears the articular surface for the carpals. The ulna has a pronounced ***olecranon*** process, that acts as a lever for the fore arm. Distally it

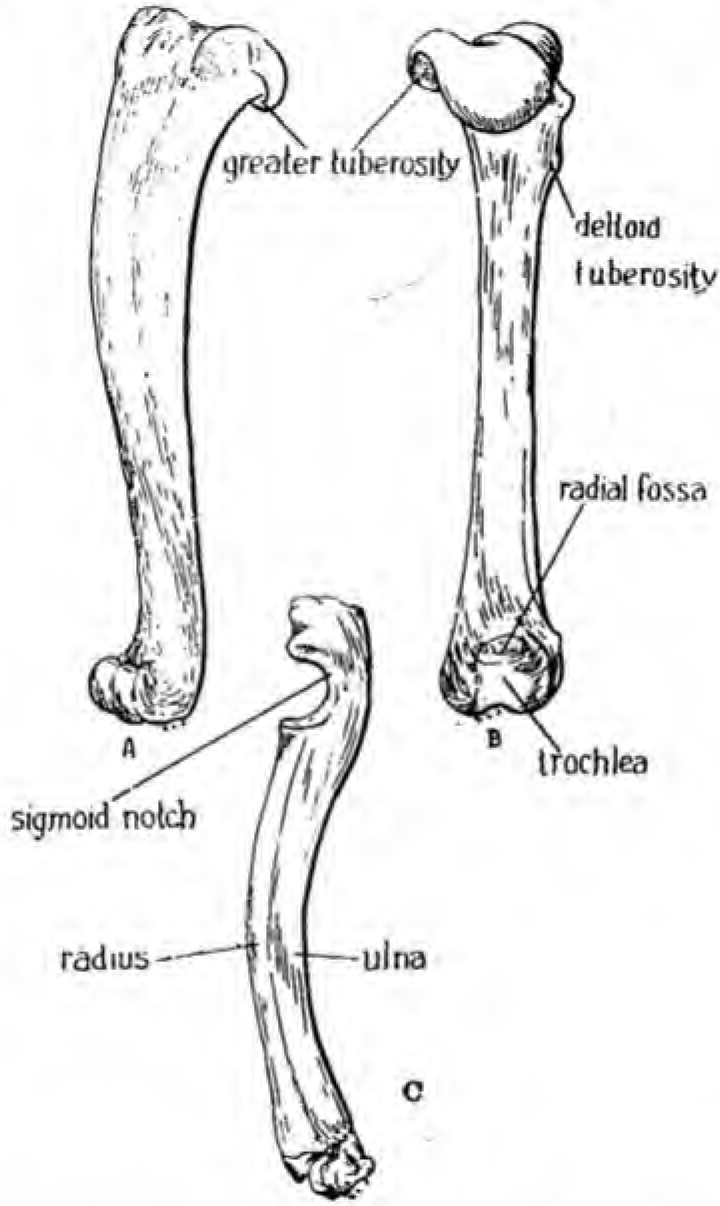


FIG. 430. Skeleton of the fore limb of rabbit. A. Posterior and B. anterior views of humerus. C. Radius-ulna in side view.

extends beyond the radius. The radius forms with the trochlea humeri a hinge-joint or ***ginglymus***. The ulna and radius being immovably united together proximally, the rabbit cannot rotate the palm, as is possible in man.

The distal segment includes the carpals, metacarpals and phalanges. The carpals are nine bones arranged in two rows. The proximal row contains the ***navicular***, the ***lunate***, the ***triquetral*** and the ***pisiform*** bones. The navicular and lunate articulate with the radius ; the triquetral and pisiform articulate with the ulna. The distal carpals include the ***greater multangular***, the ***lesser multangular***, the ***central***, the ***capitate*** and the ***hamate*** bones.

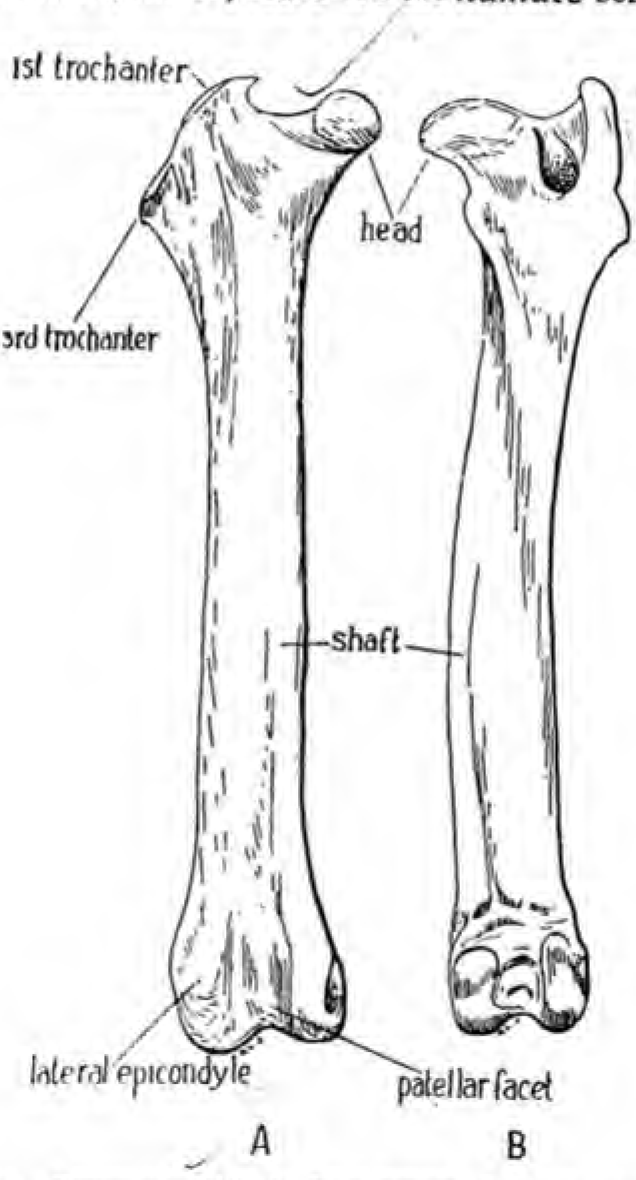


Fig. 431. Femur of rabbit A. front aspect, B. back aspect.

The metacarpals comprise five bones that form the supports for the phalanges. The phalanges are two in the thumb, three each in the rest of the digits.

THE HIND LIMB

The hind limb is serially homologous with the fore limb. The femur, corresponding to the humerus, is a long bone, with a slightly curved shaft. The ***head*** articulates with the acetabulum. At the proximal extremity the ***greater trochanter*** serves for muscle attachment. The hook-like ***third trochanter*** is a smaller lateral process. The ***lesser*** or ***second trochanter*** lies on the inner side. Distally, the

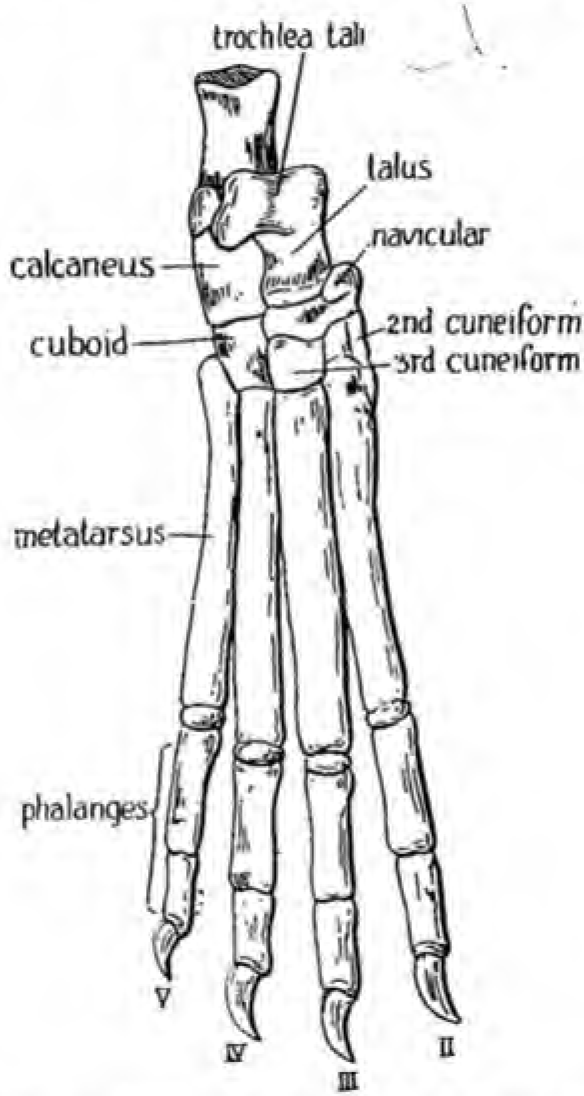


FIG. 432. Skeleton of the foot of cat viewed from above.

femur has a ***medial*** and a ***lateral condyle***, separated by an ***intercondylar fossa***. The ***patellar surface*** accommodates the ***patella*** or knee-cap. The tibia and fibula correspond to the radius and ulna. The tibia is larger than fibula and lies on the mesial side. It is fused with the fibula for more than half its length. The

triangular proximal end has a ***medial*** and a ***lateral articular*** surface to correspond to the medial and lateral condyles of the femur. The free part of the fibula is merely a splint. The combined distal ends of the tibia and fibula form the articular surface for the tarsus.

The tarsus consists of a proximal and distal row of bones. The ***talus*** and ***calcaneus*** constitute the proximal row. The ***navicular*** lies

FIG. 433. Tibia and fibula of rabbit.

between the proximal and distal rows. The distal tarsals include the ***second*** and ***third cuneiform*** bones and the ***cuboid*** bone. The metatarsus comprises four bones, which are longer than the metacarpals. The innermost metatarsal is vestigial. The phalanges are three in each of the toes except the innermost, which lacks the phalange.

7. THE NERVOUS SYSTEM

The nervous system of the rabbit includes a ***central*** and an ***autonomous*** system.

Central nervous system comprises the brain, the spinal cord and their nerves.

The Brain.—The brain is contained in the cranium and is enveloped by connective tissue membranes called ***meninges.*** The outermost membrane is the thick, tough fibrous ***dura mater.*** Beneath this lies the thin and vascular ***pia mater***. The delicate ***arachnoid*** membrane lies in between the dura mater and pia mater.

The brain (Figs. 434, 435) comprises 1. the ***prosencephalon,*** 2. the ***mesencephalon*** and 3. the ***rhombencephalon.***

Prosencephalon.—The paired ***cerebral hemispheres*** constitute the dominant portion of the brain. Dorsally they are closely united but are separate ventrally behind. The external layer or ***cortex*** is smooth and does not form convolutions as in the human brain The ***olfactory bulb*** lies at the anterior end of each cerebral hemisphere.

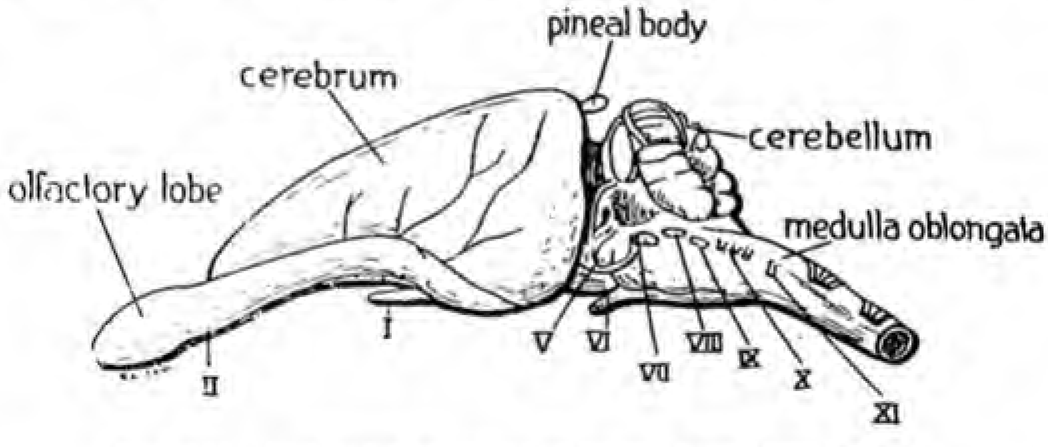


FIG 434. The brain of rabbit in lateral view from the left.

The cortex of the two cerebral hemispheres is connected together by a white transverse band, the ***corpus callosum,*** to co-ordinate their action.

The diencephalon is partly covered by the cerebral hemispheres. It bears the ***pineal body*** on a hollow stalk. On the ventral surface of the diencephalon is the ***optic chiasma*** Immediately behind it lies the ***hypophysis*** or ***pituitary body,*** attached by the ***infundibulum***. The narrow third ventricle of the brain is contained in the diencephalon. The third ventricle opens into the lateral ventricles by the foramen of munro. The side wall of the diencephalon is thickened into the ***optic thalami***. The anterior ***chorioid plexus*** forms its roof.

Mesencephalon—The boundary between the prosencephalon and mesencephalon is marked dorsally by the anterior edges of the ***four*** optic lobes or ***corpora quadrigemina.*** The anterior pair of lobes

of the corpora quadrigemina correspond to the optic lobes of the frog and are called ***colliculi superiores***. The posterior pair or ***colliculi inferiores*** serve as important reflex centres of the auditory system. Ventrally the mesencephalon is very short. It is occupied by a pair of ridges, the ***crura cerebri***. The cavity of the mesencephalon forms the narrow ***iter***.

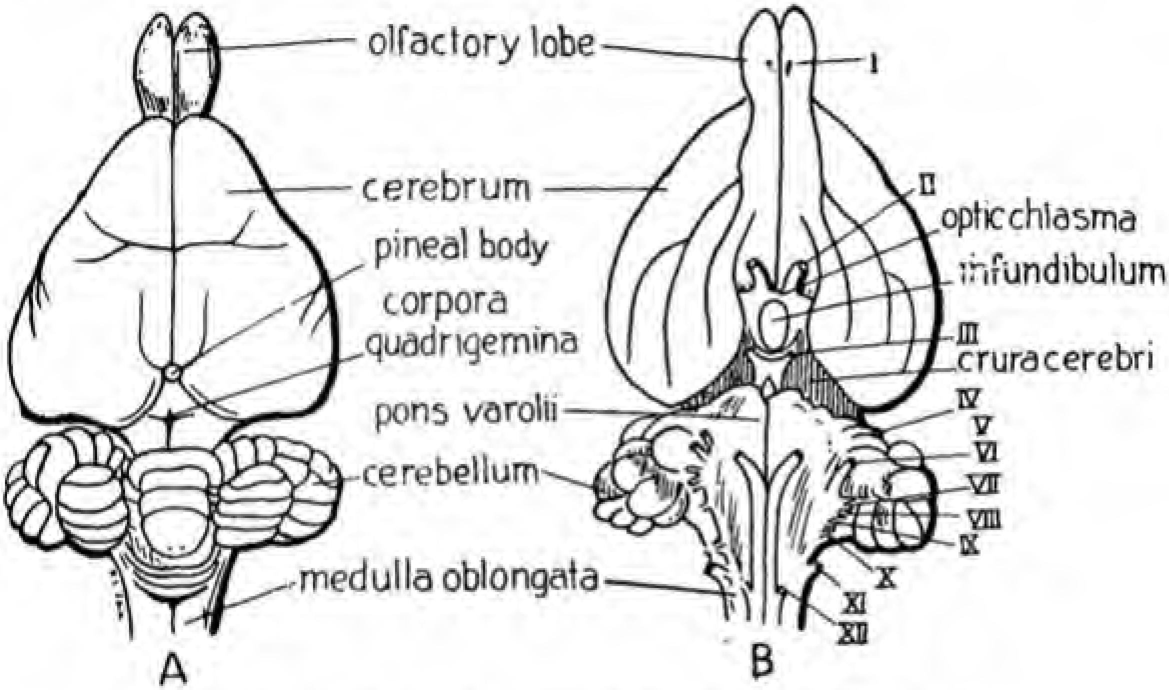


FIG. 435. The brain of rabbit in A. dorsal and B. ventral view.

Rhombencephalon.—The rhombencephalon comprises the ***cerebellum*** and the ***medulla oblongata***. The cerebellum forms a dorsal arch over the anterior part of the hind brain It is lobed and its superficial grey matter, called ***cerebellar cortex***, is thrown into numerous transverse folds. The lobes of the cerebellum are five : ***vermis*** or the median lobe, a pair of ***cerebellar hemispheres*** or lateral lobes, and a pair of ***paraflocculus***.

The cerebellum is concerned chiefly with the co-ordination of muscular action. It regulates the muscular "tone" and helps maintenance of equilibrium of the body.

In order to co-ordinate their actions, the cerebellar and cerebral hemispheres are closely associated together. The ***pons varolii***, a transverse band of nerves on the ventral surface of the cerebellum, forms a part of the path from the cerebral to cerebellar hemisphere.

The part of the brain that lies behind the pons is the ***medulla oblongata.*** The medulla continues behind into the spinal cord. It encloses the ***fourth ventricle,*** that opens in front into the ***iter.*** The ***posterior chorioid plexus*** forms its roof.

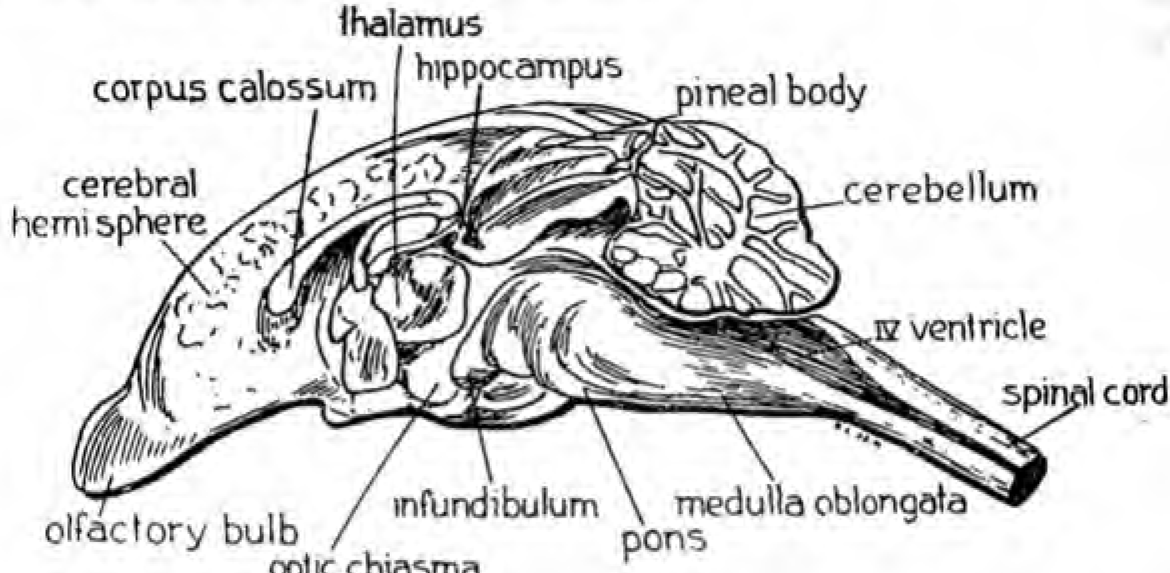


FIG. 436. The brain of rabbit in median longitudinal section.

Cranial Nerves

Twelve pairs of nerves arise from the brain. Some of these are *sensory*, others are *motor* and still others are *mixed*.

1. The ***olfactory*** or the first cranial nerve arises from the ventral surface of the olfactory lobe. It is not a compact bundle but forms numerous threads that come form the mucous membrane of the nose through the apertures of the cribriform plate.

2. The ***optic*** or the second nerve arises from the floor of the diencephalon in front of the infundibulum. The nerves of the two sides cross at the ***optic chiasma.*** They leave the cranium by the optic foramen and enter the eye ball Within the eye the nerve spreads out on the retina.

3. The ***oculomotor*** or the third nerve arises from the ventral surface of the crura cerebri. It leaves the cranium by the anterior foramen lacerum (or sphenoid foramen). It innervates the superior, anterior and inferior rectus muscles and the inferior oblique muscle that rotate the eye

4. The ***trochlear*** or the fourth arises behind the optic lobes from the rhombencephalon and makes its exit through the anterior foramen lacerum. It innervates the superior oblique muscle of the eye.

5. The ***trigeminal*** or the fifth is an important nerve. It arises by two roots from the anterior end of the medulla. They form the ***gasserian ganglion*** and soon afterwards divide into ***ophthalmic, maxillary*** and ***mandibular*** nerves. The ophthalmic branch makes its exit by the anterior foramen lacerum and passing over the eye, innervates the skin of the nose, orbit and snout. It is a sensory nerve. The maxillary branch, also a sensory nerve, similarly makes its exit and running below the eye, innervates the maxilla, the palate, upper teeth and the skin of the snout. The mandibular branch is a mixed nerve that leaves the cranium by the foramen ovale. It enters the lower jaw and innervates the lower teeth and the muscles that move the lower jaw. It also sends a sensory branch to the tongue.

6. The ***abducens*** or the sixth nerve arises from the floor of the medulla. It makes its exit from the cranium by the anterior foramen lacerum. It innervates the external rectus muscles of the eye ball. It is a motor nerve.

7. The ***facial*** or the seventh nerve arises from the side of the medulla and makes its exit from the skull by the stylomastoid foramen. It also gives a ***palatine*** nerve to the roof of the buccal cavity. The main nerve innervates the muscles of the face. Some of its branches reach the tongue and are sensory. The facial nerve is thus a mixed nerve.

8. The ***auditory*** or the eighth nerve (also called ***acoustic*** nerve) arises together with the seventh. It enters the periotic bone and innervates the internal ear. It is mainly a sensory nerve that is concerned with hearing.

9. The ***glossopharyngeal*** or the ninth nerve arises by several roots from the medulla and enlarges to a ganglion at once. It makes its exit from the cranium by the posterior foramen lacerum. It is a mixed nerve that innervates the tongue and pharynx.

10. The ***pneumogastric*** or ***vagus*** is the tenth cranial nerve that arises close by the glossopharyngeal. It also forms a ganglion. It makes its exit by the posterior foramen lacerum and runs down the neck by the side of the carotid artery. It gives off several branches: 1. ***superior laryngeal*** to the muscles of the larynx, 2. ***cardiac depressor*** to the heart, 3. ***recurrent laryngeal*** also to the muscles of the larynx, in addition to numerous other nerves to the heart, lungs and stomach.

11. The ***spinal accessory*** or the eleventh nerve arises from the anterior end of the spinal cord but enters the cranium through the foramen magnum. It then unites with the vagus nerve and makes its

exit from the cranium again through the posterior foramen lacerum. It is a motor nerve that innervates the muscles of the neck.

12. The ***hypoglossal*** or the twelfth nerve arises from the posterior part of the medulla and makes its exit through the condylar foramen. It is a motor nerve that controls the movements of the tongue.

The spinal cord.—The spinal cord is really a continuation of the medulla oblongata into the vertebral column. It is a thick, subcylindrical white cord enclosed in the neural canal of the vertebrae. It extends as ***filum terminale*** into the tail. It is not uniform in its thickness, but is enlarged somewhat in the neck and again in the lumbar region. The cervical and the lumbar enlargements are the regions from which arise the nerves of the fore- and hindlimbs As in the frog, the spinal cord has a ***dorsal fissure***, a ***ventral fissure*** and a ***central fissure*** and a ***central canal*** running the whole length. The inner part is composed of grey and the outer of white matter. The grey matter is H-shaped in section, each half being produced into ***horns*** or dorsal and ventral columns. Like the brain, the spinal cord is also ensheathed by pia mater and dura mater. The spinal cord is concerned in reflex action.

Spinal nerves—The spinal nerves arise by two roots, viz. dorsal and ventral. The dorsal is sensory and forms a ganglion. The ventral is motor. The impulses that pass through the dorsal root are thus ***centripetal*** or ***afferent***. The ***centrifugal*** or ***efferent*** impulses pass through the ventral roots and often produce muscular contraction. Directly outside the spinal cord the two roots unite together but redivide further on into a ***dorsal ramus*** and a ***ventral ramus*** or into ***ramus communicans*** that connects with the autonomus system.

There are thirty-seven pairs of spinal nerves, which arise regularly as below : eight in the cervical region, twelve in the thoracic, seven lumbar, four in the sacral and six in the caudal. The spinal nerves leave the vertebral column by the intervertebral foramina. Most spinal nerves supply the body wall. The third spinal nerve also sends a branch to the pinna of the ear. Branches from the fourth, fifth and sixth spinal nerves unite to form the ***phrenic nerve***, that runs to the diaphragm. It controls the respiratory movements of the diaphragm. The fifth to the eighth of the cervical spinal nerves and the first thoracic spinal nerve form the ***brachial plexus***. This plexus sends branches to the shoulder and forelimbs. The last four lumbar and first sacral spinal nerves similarly form the ***lumbo-sacral plexus***, that sends branches to the hindlimbs.

The autonomous nervous system —The autonomous nervous system of the rabbit is similar to that of the frog. It comprises a ***sympathetic trunk***, one on either side ventrally of the vertebral column. The sympathetic trunk extends from the origin of the trigeminal nerve to the posterior end of the body. It is ganglionated at intervals The ramus communicans from the spinal nerve is connected with each of these ***sympathetic ganglia***. The sympathetic trunk is also connected with a ***collateral*** series of ganglia and through them with ***peripheral ganglia*** on the surface of the visceral organs. Nerve branches run from these ganglia to the visceral muscles and glands.

A ***parasympathetic*** part of the autonomous nervous system comprises the connections with the sacral and third, seventh, ninth, tenth and eleventh cranial nerves. The parasympathetic portion does not join the sympathetic trunk, but its fibres connect with only peripheral ganglia.

Sense organs

The ***olfactory*** sense organ comprises neuro-epithelial cells imbedded in the mucous membrane of the nasal chamber. The outer end of each is ciliated. At its inner end it gives rise to an unmyalinated nerve fibre that runs through the olfactory nerve to end in the olfactory bulb of the brain.

Groups of minute fusiform cells in the stratified epithelium of the buccal cavity constitute the ***gustatory*** organs. Microscopic ***taste buds*** occur on the fungiform, vallate and foliate papillae on the dorsal surface of the tongue.

The ***eye*** of the rabbit is built on the same plan as that of the frog. It is essentially a specialized part of the brain, viz. the ***retina*** that grows out on the end of the optic nerve. It is the light-sensitive surface on which the ***lens*** focusses images of objects. The whole structure is enclosed in a protective and light-excluding capsule or ***eyeball***. The eyeball is nearly spherical. It is composed of dense connective tissue that forms the outer white opaque fibrous ***sclerotic coat***. The exposed surface of the eyeball is the transparent ***cornea*** and here the sclera is absent. The cornea is a transparent sheet of connective tissue, that is a highly refractive curved surface.

The ***vascular tunica*** is a pigmented thin middle coat, that comprises the ***chorioid*** on the inner surface of the sclera, a muscular ***ciliary*** body and ***iris***. The ciliary body is composed of numerous,

radial ***ciliary folds*** and forms a ring about the edge of the lens. The iris is a circular fold of deeply pigmented muscular diaphragm that adjusts the amount of light entering the eye. The aperture of the iris diaphragm is the ***pupil***. The ***lens*** is smaller than in the frog and biconvex, with the outer surface flatter than the back. It is suspended by fine ***zonular fibres***, which are the folded margins of the ciliary body. Normally the zonular fibres remain in a state of tension that maintains the flatter shape of the lens. The eye is thus focussed at "infinity" and is at rest. Contraction of the muscles of the ciliary body releases the tension and the lens becomes more convex by its own elasticity. The eye now becomes focussed near at hand. The eye of the rabbit can thus be compared to a "bellows-camera" in which sharp focussing of objects at different distances is possible. The focussing is not however done by moving the lens back and forth as in the camera but by changing its curvature. This capacity for adjusting the eye for distant and near vision is called ***accommodation***. The frog's eye lacks the power of accommodation.

The space between the cornea and the lens is filled with ***aqueous humor***, and consists of an ***anterior chamber*** in front of the iris and a ***posterior chamber*** behind it. The two chambers communicate with each other through the pupil. The space behind the lens is the dark room that is filled with ***vitreous humor***, a transparent jelly-like mass.

The retina is the soft, light-sensitive membrane covering the inner surface of the chorioidea. The place of entry of the optic nerve is not sensitive to light and constitutes the ***blind spot***.

The retina is composed of several layers. Its outermost layer is composed of pigmented epithelial cells. ***Rods*** and ***cones***, that are the actual nerve endings, project among these cells. The rods are sensitive to dim colourless light and the cones are the colour receptors and are active in bright light. The rabbit has very few cones and it is therefore nearly colour-blind.

The eyeball is enclosed in the orbit and is rotated by the following muscles in the rabbit: obliquus superior and inferior; recti superior, inferior, medials and laterals and rectractor oculi.

The ***Harderian gland*** is a lobulated mass in the anterior part of the orbit. It consists of two portions: a large, pale red postventral lobe and a white anterodorsal lobe. They open by a common duct on the inner surface of the nictitating membrane. The Harderian gland is absent in man. The temporal region of the orbit encloses the smaller

darker and lobulated ***lachrymal gland*** (also spelt lacrimal). Several lachrymal ducts open within the upper eyelid.

The ear.—The ear is the ***sound receptor*** and ***static organ*** or receptor for equilibrium stimuli. The actual sensory areas are the walls of the ***membranous labyrinth*** (Fig. 437).

The ear includes the ***external, middle*** and ***internal*** ears. The external ear comprises the ***pinna*** and the external ***auditory meatus***. At the bottom of the meatus is stretched the ***tympanum***. The pinna serves to collect and transmit the sound waves down to the tympanum. The middle ear is behind the tympanum and lies in the tympanic cavity of the tympanic bulla. The ***eustachian tube*** connects the tympanic cavity and the pharynx and equalizes the pressure on both sides of the tympanum. The chain of the delicate ***auditory ossicles*** lies in the

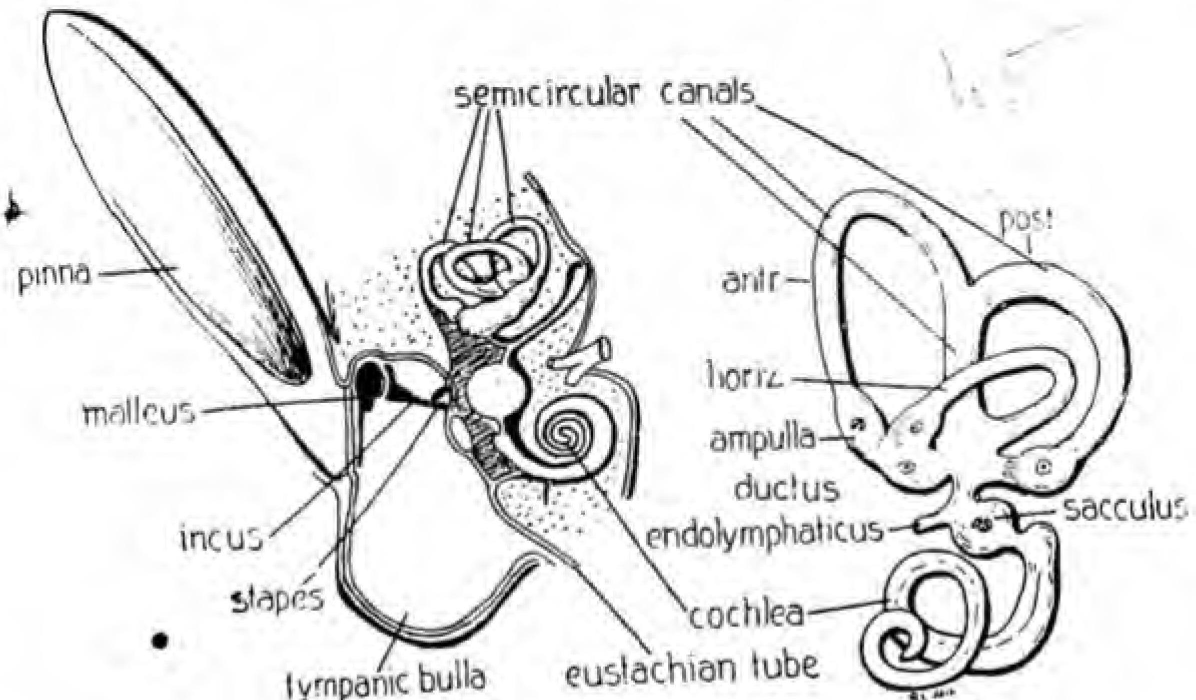


FIG. 437. The auditory organs of rabbit. A. Vertical section through the auditory capsule of the skull showing the essential parts in situ. B. The membranous labyrinth.

tympanic cavity. The ***malleus*** is in contact with the tympanum. It articulates with the ***incus*** and the latter with the ***stapes***. The stapes loosely plugs the ***fenestra ovalis*** in the periotic bone. The fenestra ovalis is really an opening in the ***bony labyrinth*** corresponding exactly to the membranous labyrinth that it contains.

The internal ear includes the membranous labyrinth enclosed in a corresponding bony labyrinth. The membranous labyrinth of the rabbit is essentially the same as in the frog. It comprises the ***utriculus,*** into which open the three ***semicircular canals.*** The semicircular canals are anterior, posterior and horizontal, each perpendicular to the other. Each semicircular canal has an ***ampulla*** at one end. The semicircular canals constitute the static receptor part of the membranous labyrinth. The ***ductus endolymphaticus*** from the utriculus runs to the cranial cavity and ends in a blind sac within dura mater of the brain. The sacculus is connected with a spirally coiled ***cochlea*** or the auditory portion of the membranous labyrinth. Within the cochlea is the complex ***organ of corti*** that contains the fine endings of the actual auditory sensory nerves. The cavity of the bony labyrinth is filled by ***perilymph*** fluid and the membranous labyrinth by ***endolymph.***

Changes of position of body in any of the three planes cause the flow of the endolymph in one or more of the semicircular canals. The receptor nerve endings in the ampulla perceive and transmit these movements to the brain. The nerve endings in the utriculus and sacculus respond to the gravitational change of position. The vibrations of the tympanum caused by sound waves are transmitted by the auditory ossicles to the labyrinth and cause corresponding waves or changes in the pressure of the perilymph. These vibrations are perceived by the organ of corti.

RESUMÉ

1. The rabbit is a herbivorous mammal belonging to the order Lagomorpha. It is essentially a burrowing animal.

2. The body of the rabbit is clothed by hairs. Some of the hairs are modified as vibrissae. The pinna of the ear is long. Eyes have movable lids. The urinogenital aperture is separated by the perineum from the anal aperture.

3. A muscular diaphragm divides the thoracic from the abdominal cavity.

4. The alimentary canal includes the salivary glands and a capacious caecum.

5. There is a four-chambered heart in which the venous blood is confined to the right side and the arterial blood to the left side.

6. The arterial system consists of the pulmonary artery from the right ventricle and of the left aortic arch from the left ventricle. The aortic arch gives off carotid and other arteries and continues as the dorsal aorta.

7. The venous system consists of the pulmonary vein, the two precavals and the postcaval that open into the left auricle There is only the hepatic portal but no renal portal system.

8 The lungs are filled and exhausted by the action of the diaphragm and of the intercostal muscles.

9. The kidneys are the excretory organs. The ureters leave the kidneys from the mesial side and open into the urinary bladder. There is no cloaca. The urethra from the bladder joins the genital ducts to form the urinogenital sinus.

10. The testes are abdominal at first but later descend into the scrotum to become inguinal. Part of the vas deferens forms the epididymis. The penis bears the outer opening of the vas deferens. The ovaries are abdominal. Each ovary contains numerous graafian follicles enclosing the ova. The fallopian tubes open close by the ovaries and enlarge behind into the uterus. The uterus of each side communicates behind into the vestibule that opens to the outside by the vagina.

11. The vertebrae are platycoelous. There are seven cervical vertebrae that are recognized by the costo-transverse foramina The axis vertebra has a conspicuous odontoid process. Thoracic vertebrae have costal facets for the articulation of ribs. The os sacrum comprises four fused vertebrae. Caudal vertebrae are mostly reduced to mere cylinders.

12. The ribs form a basket-work enclosing the thoracic viscera.

13. The skull is completely ossified except for the mesethmoid. The floor of the cranium is formed of primary bones and the roof of dermal bones. There is no parasphenoid. The lower jaw is articulated to the squamosal. There is a conspicuous zygomatic arch. The quadrate is reduced to the minute incus of the middle ear.

14. The pectoral girdle is reduced to the scapula and a slender clavicle. The pelvic girdle has an obturator foramen, a pelvic symphysis and an acetabulum.

15. In the limbs the radius and ulna and the tibia and fibula are nearly separate.

16. The cerebral hemispheres are large. The corpus callosum co-ordinates their activities The cerebral cortex is an important feature of the rabbit brain.

17. In addition to the ten pairs of cranial nerves found in the frog, the rabbit has an eleventh spinal accessory and a twelfth hypoglossal pair.

18. The eye has flatter lens than in the frog. The curvature of the lens is capable of being adjusted for focussing objects at different distances.

19. The membranous labyrinth is enclosed in a bony labyrinth. The semicircular canals, utriculus and sacculus are static organs. The cochlea is the auditory portion

CHAPTER XXIV

ANTHROPOID APES AND MAN

A. ANTHROPOID APES

The ANTHROPOID (=man-like) apes are arboreal mammals, that lack cheek-pouches and tail. They are so called because of their close resemblance to human beings. There are four genera represented by living species at present : gibbons, orangutans, chimpanzees and gorillas. These apes can assume a semi-erect posture. They have all opposable thumbs and great toes. Except the gorilla, they are essentially tree-dwellers. The scapula and the arms are long and adapted for ***brachiation*** or swinging by the arm (Fig. 438). The hands and feet are adapted for grasping the branches. The jaws and teeth are powerful. Apes cannot articulate words.

The ***gibbons*** (family PONGIDAE) (Fig. 438) are completely arboreal but often descend to the ground and run erect. They can even walk on swaying branches or ropes without losing balance and falling down. There are two species : *Hylobates lar* the white-handed gibbon and *H. hoolock* the hoolock gibbon. They inhabit the dense forests of Assam, Burma, Siam, Indo-China, Malaya and Borneo. Their food consists of leaves, fruits and tender shoots, varied with spiders, insects and birds' eggs. Their voice is powerful, resembling human wailing at a distance. They call each other from sunrise to about 10 A. M., then feed or rest and resume calling in the evening. At night they sleep sitting on the branch, with the head buried between the knees.

Pongo satyrus ("man of the forest") or the ***urangutan***, strictly arboreal, inhabits the swampy forests of Sumatra and Borneo. It stands about 4 ft. high, has sparse, coarse, red hairs. Its food comprises fruits, especially the delicious durian. The arms reach to the ankles ; the legs are short. Old males often develop long moustache. The orang has an enormous air-sac, extending from the larynx to the armpits, and serving as voice-resonater.

The ***chimpanzee***, *Anthropopithecus* or *Pan troglodytes*, inhabits the forests of equatorial Africa. It is more human in appearance than all the other apes. The brain is highly organized. The coat is long, black or brown but the face is nearly free from hairs. The chimpanzee is easily trained to wear cloths, eat with spoon and ride tricycles. It likes human company.

The ***gorilla*** is the largest and the most man-like of all the apes. Gorillas occur in equatorial Africa. They are the strongest of all the apes and often weigh nearly 580 lbs. and stand nearly $5\frac{1}{2}$ feet high. Gorillas live

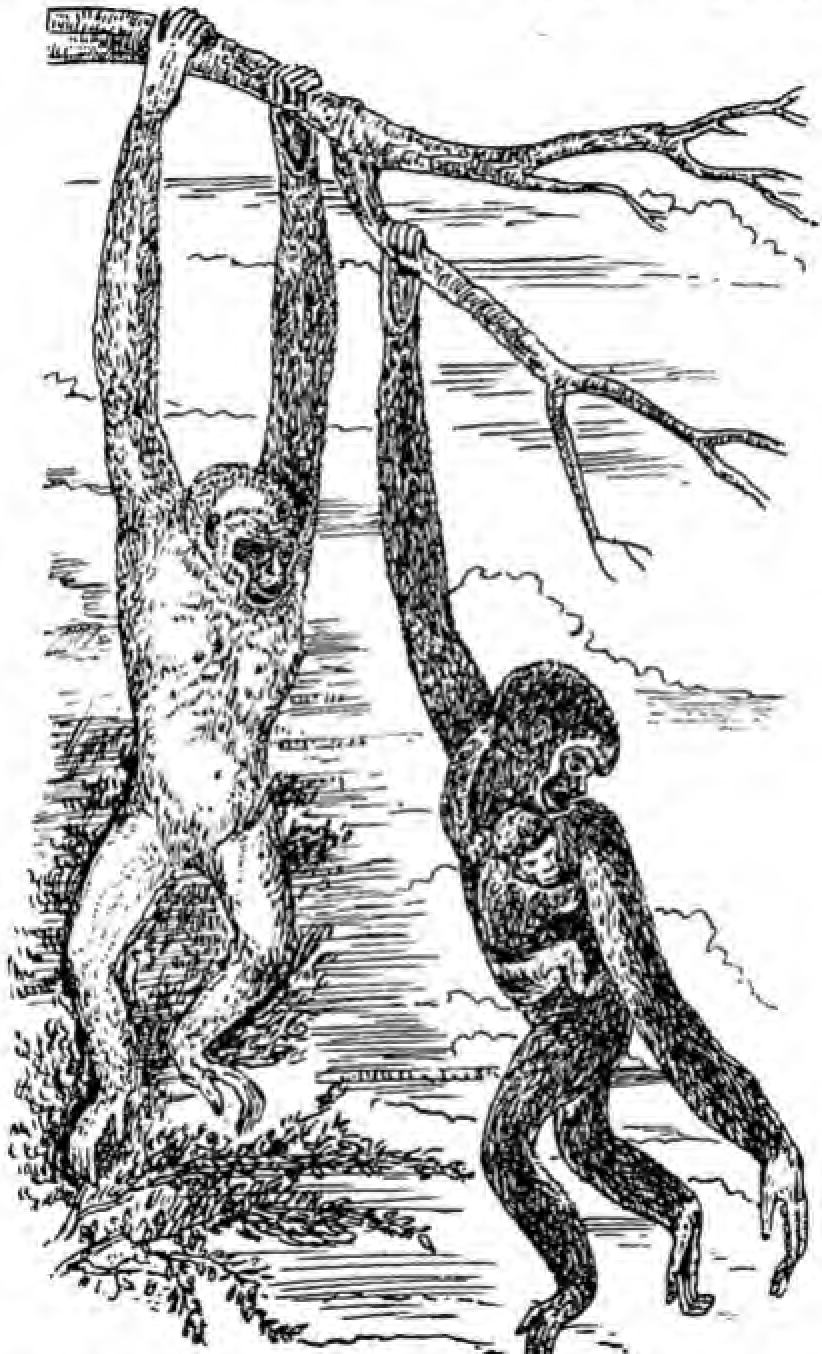


FIG. 438. *Hylobates lar*, the gibbon, is an example of extreme specialization for arboreal life. It swings on its hands from branches, feeds on leaves, fruits, flowers, spiders and insects. Gibbons occur in Siam, Tenasserim, Malaya and Lower Burma. (*From Pocock, Fauna of British India*).

in families under the leadership of an old male. They construct crude huts of sticks and leaves.

B. MANKIND

MAN'S PLACE IN THE ANIMAL KINGDOM

All living races of man are placed in one species, ***Homo sapiens*** of the family Hominidae. Man's place in the animal kingdom is as follows :

Phylum CHORDATA
  Subphylum *CRANIATA* (= Vertebrata)
    Class MAMMALIA
      Infraclass *Eutheria*
        Order Primates
          Suborder Pithecoidea
            Superfamily Hominoidea
              Family Hominidae
                Genus *Homo*
                  Species *sapiens*.

The family HOMINIDAE is distinguished from PONGIDAE (apes) by the following characters :

1. Man is completely terrestrial, highly gregarious, social and omnivorous.
2. Erect posture is complete and more perfect than in the apes.
3. Brain is of far greater functional ability, of larger size and of greater complexity.
4. The skeleton is of different proportions.
5. Face flatter and more vertical than in the apes.
6. Brow ridges less prominent.
7. Lower jaw less projecting.
8. Teeth nearly evenly sized.
9. Hair long and growing continually on head but sparse and short on the body.
10. Arms shorter and more generalized.
11. Thumb better developed.
12. Big toe not opposable.
13. Voice can be articulated into speech.

Erect posture. The erect posture or the ability to stand and move on two legs distinguishes man from all other animals. This frees the forelimbs from the burden of supporting the body. The arms and hands are thus free to pick up food, convey it to the mouth, or hold it for close inspection by the eyes. Man's ability to make and use tools, in fact human

civilization, is directly due to 1. the gripping capacity of the hand *inherited* from ancient arboreal life and 2. perfection of the erect posture. Assuming an erect posture has caused several other modifications : the vertebral column curves forward in the neck and lumbar regions. The centra of the lower vertebrae are large to support the weight above. The pectoral girdle is light and less firmly attached but the pelvic girdle becomes strongly developed. The foot is arched to absorb shock and jars due to contact with the ground.

Size.—The normal size of man is about 5½ to 6 feet. Exceptionally midgets measure only 3 feet tall and giants exceed 9 feet. Men living in countries of extremes of climate are usually short but those living under temperate conditions are tall.

Skin.—The human skin is thin and delicate. It is thickened into ***calluses*** only on the sole of the palm and feet. The skin colours are white, yellow, brown and black. Human skin is rich in sweat glands. The human hair differs in length and amount according to sex and race. The Oriental races have, for example, straight black hair and the Negroes have woolly and kinky hairs.

Teeth.—(Fig. 439) Man being omnivorous, his teeth are less conspicuously differentiated than in many mammals. The teeth are also of nearly equal height. The milk teeth are 20 and the permanent vary from 28 to 32.

Reproduction.—***Puberty*** is the time when human beings reach sexual maturity. It varies from 14 to 17 years of age and is characterized by marked changes. In the males the beard and the body hair grow and the shoulders broaden. The voice deepens in pitch. In the females, this period is marked by the enlargement of the mammary glands and hips and deposition of subcutaneous fat. A recurrent discharge of blood, mucus and epithelial cells from the uterus (Fig. 443) constitutes ***menstruation*** about every 28 days. This discharge is regulated by the endocrine secretions. Menstruation ceases during pregnancy and lactation and also after about 45 years of age. One ovum passes down into the uterus some days after a menstruation ; a woman altogether passes out nearly 400 ova during her life.

The fertilized ovum gets ***implanted*** in the mucous lining of the uterus. Shortly after the formation of the embryonal envelopes, a placenta appears. The embryo completes its development in about 280 days. In the vast majority of cases, a woman gives birth to only one infant at a time. Twins, triplets, quadruplets and quintuplets are known. Out of every 88

births one is a twin ; one a triplet out of every 7600 births ; and quadruplets out of 670,000. Fifty known cases of quintuplets have been recorded but only exceptionally, as for example, the famous Dionne quintuplets, all the infants survive.

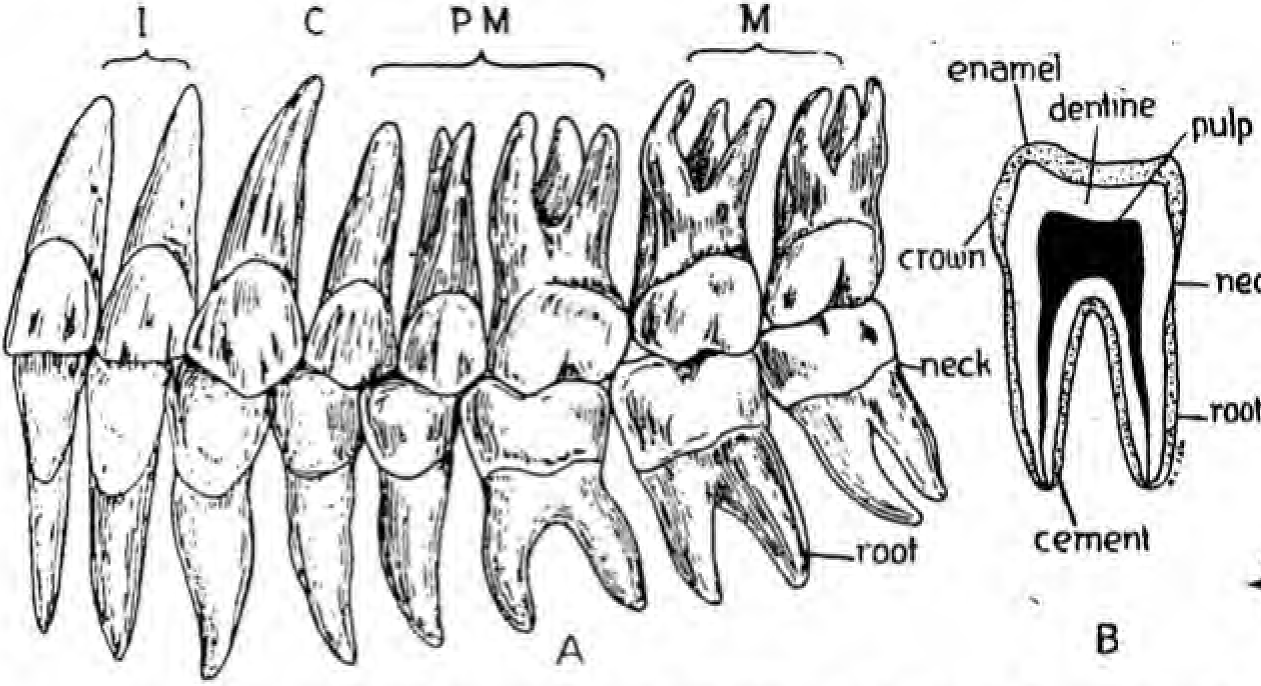


FIG. 439. The human dentition. A. Upper and lower teeth. B. Section through a typical molar tooth. The teeth of man are the least specialized: they are adapted for an omnivorous diet.

Classification.—

All the human beings living at present belong to a single variable species *Homo sapiens*, divided into numerous ***races***, that freely interbreed. Distinct races of mankind have been blended by intermarriages, so that a clear-cut delimitation is not always possible. ***Anthropologists*** distinguish the races of mankind by differences in 1. the form of the hair—straight, smooth or curly—, 2. hair colour, 3. skin colour—white, yellow, brown or black—, 4. form of head, 5. facial features and 6. stature.

Species *Homo sapiens*

Group I. NEGROID. Hair woolly ; skin dark ; nose broad and flat ; lips thick ; eyes prominent ; teeth large.

Race i. NEGRILLO. Skin yellow ; hair short, dusty brown ; stature 56″. Congo pigmy men of forests of equatorial Africa.

Race ii. BUSHMAN. Skin yellow ; hair short ; buttocks enlarged in females; stature 60″. Kalahari desert of Africa.

Race iii. NEGRO. Skin black ; head long ; legs short ; stature 68″. Formerly from tropical Africa now in Guinea.

Race iv. NEGRITO. Skin dark; hair short; stature 57—60". Malaya, Andamans, Dutch New Guinea, Philippines.

Race v. MELANESIAN. Skin chocolate; head high and long; stature 63". Fiji Islands.

Group II. MONGOLOID. Hair straight, coarse, black; sparse on face; skin yellowish; face broad, with prominent cheek bones; nose small; eyes narrow; teeth moderate size.

Race i. ESKIMO. Skin yellowish-brown; face flat, round. stature 66". Greenland Arctic coasts of North America and North-eastern Asia.

Race ii. RED INDIAN. (Nothern Amerind) Skin yellow to red; nose straight or convex; stature 69". North America.

Race iii. PATAGONIAN. Skin deep brown; head short; face square; stature 72". South America.

Race iv. MONGOLS. Skin pale yellow; face round or square; stature medium. Mongolia China and Indo-China.

Race v. INDONESIAN. Skin yellow or light brown; hair black; cheek prominent; nose flat; stature short. East Indies.

Race vi. POLYNESIAN. Skin yellow or light brown; hair straight or wavy; nose prominent; stature tall. Hawaii, Samoa, New Zealand.

Race vii. TURKO TARTAR. Skin pale yellow; face long; nose straight; lips thick. Turkey and Central Asia.

Group III. CAUCASOID. Hair Straight, smooth to wavy; skin light-coloured; beard well developed; nose narrow and prominent; cheek not prominent; teeth fine and small.

Race i. AUSTRALIAN. Skin dark-brown; hair straight or wavy; forehead receding; jaw prominent; nose flat. Australia

Race ii. DRAVIDIAN. Skin dark brown; hair brownish-black; curly and abundant. South India.*

Race iii. INDO-AFGHAN. Skin light-brown; hair black; tall. Kashmir.

Race iv. ETHIOPIAN. Skin reddish-brown or dark brown; hair brown or black. North Eastern Africa.

Race v. ARMENOID. Skin black; hair dark brown; wavy and abundant; nose hooked; stature medium. North-east Mediterranean region.

Race vi. ARAB. Skin pale tawny; hair black. Arabia.

Race vii. NORDIC. Skin reddish-white; hair red or pale brown; head long; nose prominent, stature tall. Northern Europe.

STRUCTURE

The human body contains the same organ systems as in the frog or rabbit. The differences are only of proportions of various parts and no new organ system occurs in man that is not found in any other animal.

Digestive system.—The digestive system of man (pl. iv) comprises the same organs as in the rabbit. The same enzymes are secreted to split up the food into glucose, glycerol, fatty and amino acids, etc, for absorption. The caecum is however reduced to a mere vestige viz. ***vermiform appendix***. This is because man's food is not simply

* There is considerable race mixing in India; for example, the Mongoloid-Dravidian from Bengal, the Scythio-Dravidian from Bombay and the west and the Indo-Afghan-Dravidian from the United Provinces.

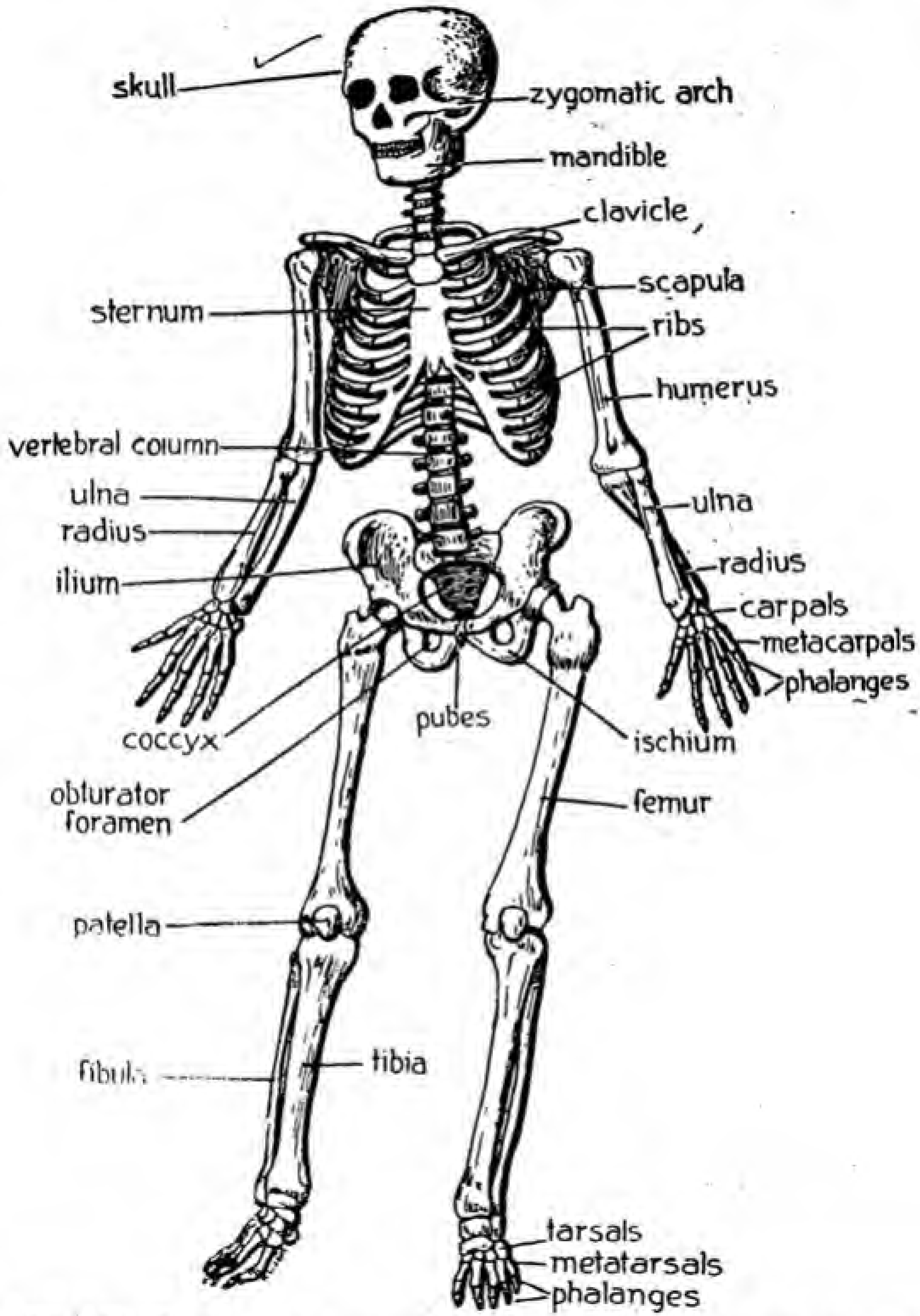


FIG. 440. The human skeleton in front view. It is remarkable for the enormous size of the cranium but consists essentially of the same bones as the frog or rabbit, that differ only in proportions.

uncooked vegetable matter; man is omnivorous and takes relatively concentrated food. A long caecum is unnecessary.

Circulatory and respiratory systems. - The circulatory system of man comprises 1. a completely four-chambered heart, 2. the left systemic arch and 3. veins. As in the frog and rabbit, the heart pumps the blood 1. to the lungs for oxygenation and 2. to various parts of the body. It thus differs from that of the shark, because in the latter

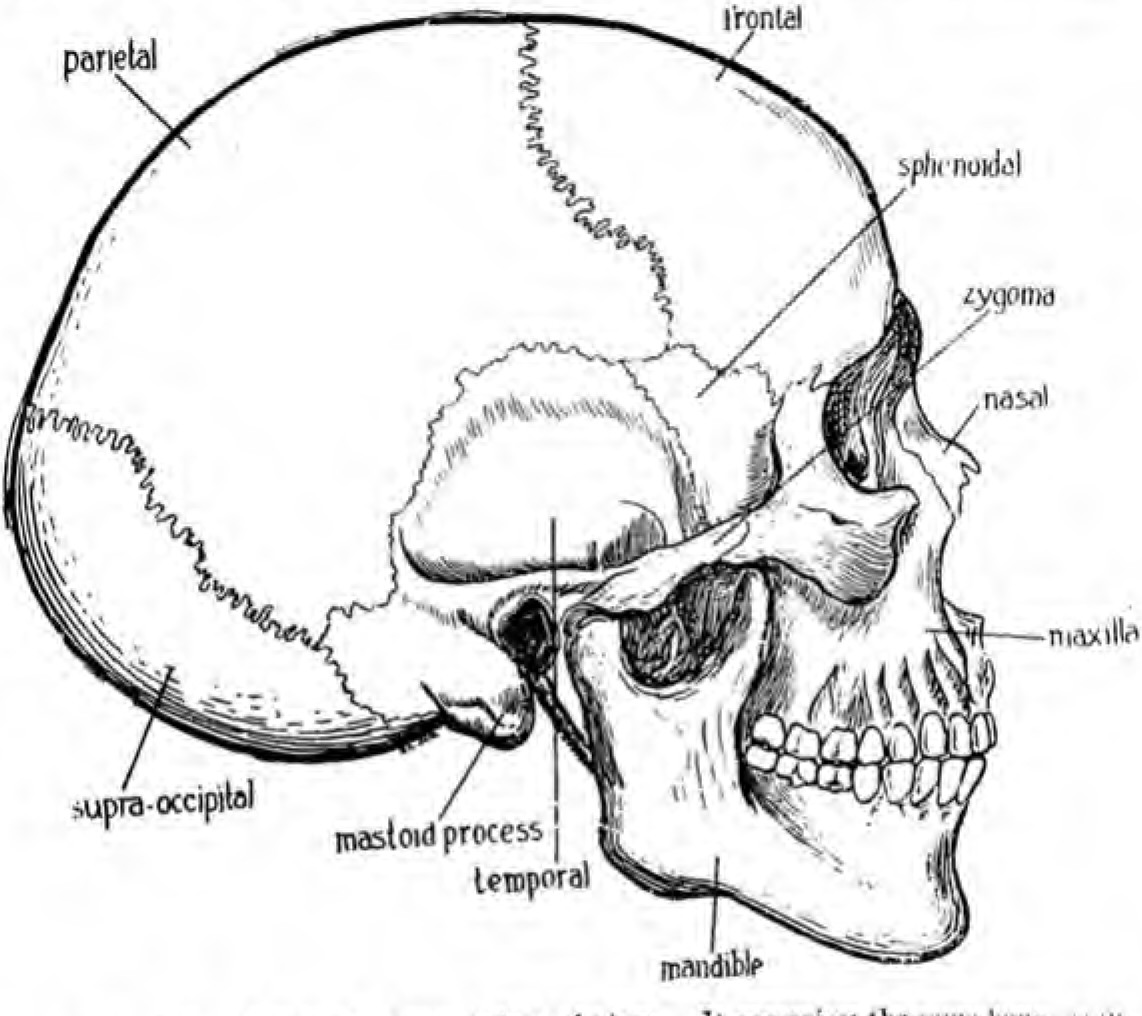


FIG. 441. The skull of man in lateral view. It comprises the same bones as in other mammals and differs only in proportions. The human skull is remarkable for the great size of the cranium, the less prominent facial part and for the generalized dentition.

animal the heart pumps the blood only to the gills. In a human embryo about 4 mm long the circulation is on the shark-like plan. The same aortic arches give off branches to the gill slits, though there is no gill in the human embryo. There is only one portal - the hepatic —circulation in man : there is no renal portal as in frog. The red corpuscles are biconcave non-nucleated bodies.

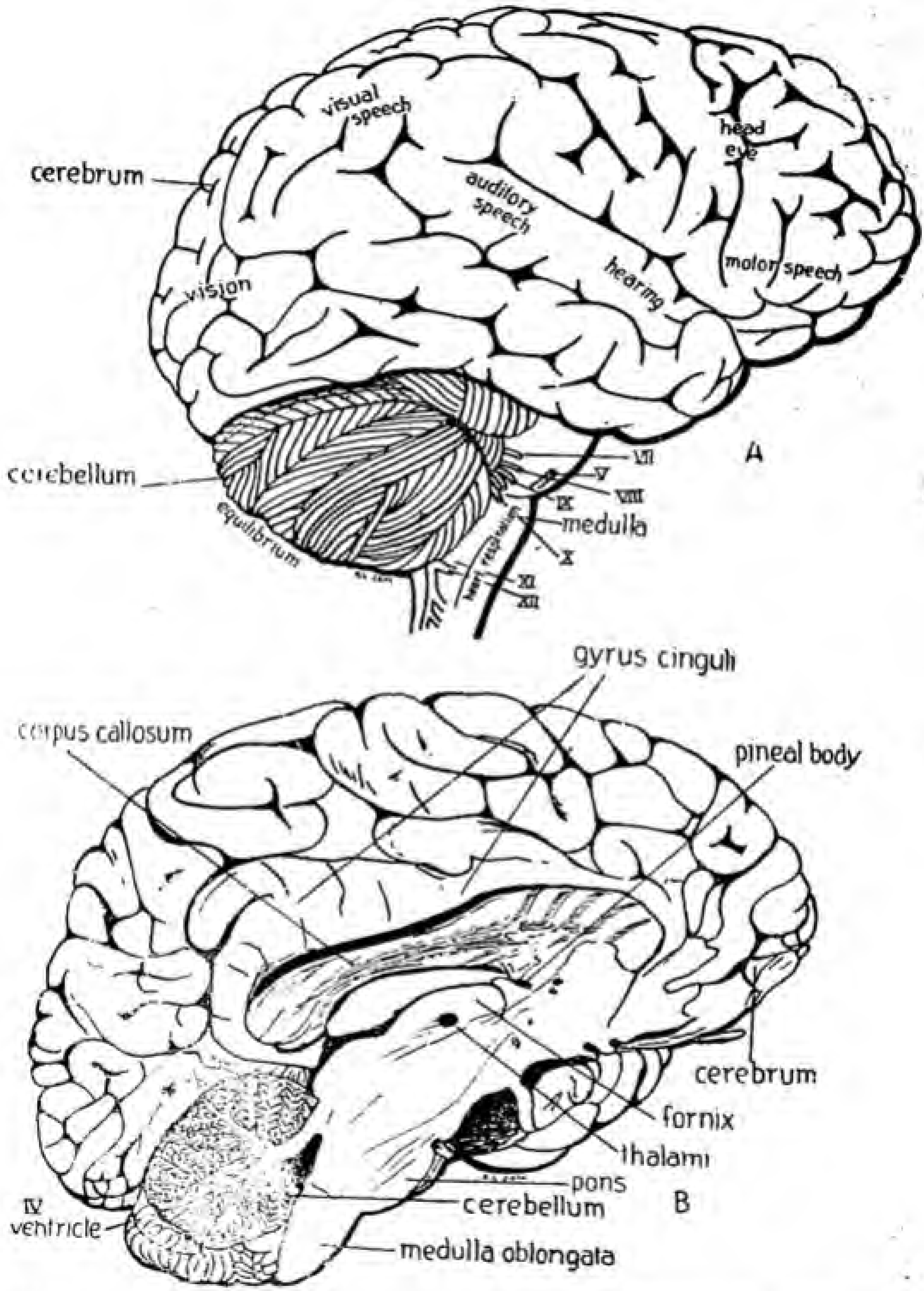


FIG. 442. The human brain is remarkable for the great size of the cerebrum but contains the same parts as in the frog. A. In lateral view from the right. B. Vertical median section in lateral view from the right.

Respiration is effected in the human being by the rhythmic movements of the ribs and the diaphragm. The ribs are set obliquely. They are pulled upward and outward by the ***scalene*** and ***intercostal*** muscles The abdominal muscles pull them forward and downward. They also rotate outward as they move upward and thus increase the chest cavity. The air pressure is reduced in the lungs and fresh air rushes in. The diaphragm acts as a kind of bellows for the chest cavity. The respiratory movement is mainly thoracic in women and diaphragmic in man.

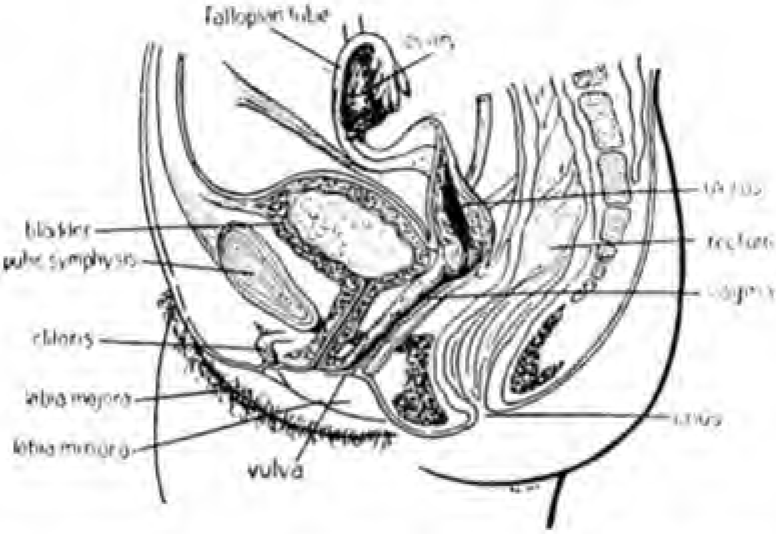


Fig. 443. Diagrammatic median section through the posterior part of the human body to show the genital and associated organs in the female.

Urinogenital system. – (Figs. 443, 444.) The kidneys are the excretory organs in man. The reproductive organs comprise ovaries and testes. The posterior parts of the oviducts unite into a thick-walled ***uterus*** or womb, in which the embryo develops. The testes descend from the abdonimal cavity into the ***scrotum*** in man and many other higher mammals.

Skeletal system –(Figs. 440, 441). The skeletal system of man contains nearly the same bones as in the rabbit, but the bones are of different proportions. The vertebral column is formed round the notochord and supports the skull, ribs and internal organs.

The skeleton is essentially the passive element of the locomotor apparatus of an animal. The primitive vertebrates lived in water and swam by undulations of the body. The fins served as rudders and balancers. In the lungfishes the fins became paddles. When animals crawled on land these became limbs. Then the animals managed to rise the belly

off the ground and next climbed trees. The limbs now served for grasping the branches. When the ancestors of man descended to the ground, they stood semi-erect. The fore limbs, now freed from locomotor function, came to be used in picking food, making tools, etc. The skeletal system of man is thus merely that of a frog or lizard perfected for an erect posture and locomotion on two legs.

Nervous system.—(Fig. 442) In addition to the ten pairs of cranial nerves of the frog, man, like the rabbit, has a pair of ***spinal accessory*** and ***hypoglossal*** nerves In lower vertebrates, like the shark, the

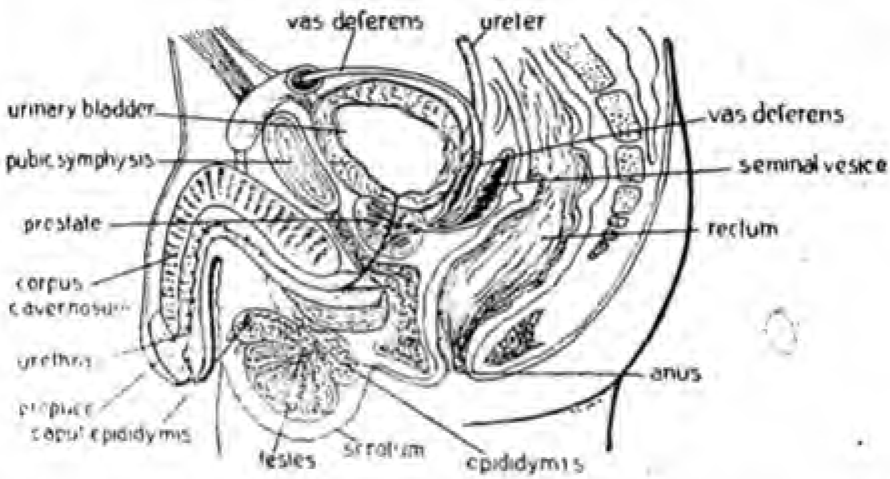


Fig. 444. Diagrammatic median section through the posterior part of the human body to show the genital and associated structures in the male.

brain serves mainly for ***smelling***, ***seeing***, ***balancing***, ***feeling*** and ***tasting***. Its actions are mostly ***reflex actions*** and are controlled by the senses. In mammals and man the reflexes are largely under the control of the brain, and actions are controlled by ***ideas***. Speech is the most important character of man.

History of Mankind

Man is a very recent creature on the earth, which is estimated to be about 3350 million years old. Hardly half a million year has passed since the appearance of human beings.

The first of the definitely human ancestors was Java Ape man or *Pithecanthropus erectus* (Figs. 445 A,B,C) Part of skull, lower jaw, femur and some teeth of this ancestor were discovered in Java. He had low cranium, heavy brow ridges and stood semi-erect. He could probably speak but perhaps made no tools. His estimated age is half a million year ago.

Sinanthropus pekinensis or the Peking man had better developed brain and could make tools of bones and stones. He also knew the use of fire.

FIG. 445. Extinct men. Man is a very recent creature on earth; the [illegible] fossil belongs to the Pleistocene—hardly a million year ago, while life has been evolving for over at least 600,000,000 years. A. Front view, B. Semiprofile and C. Profile of Ape man of Java, *Pithecanthropus erectus*, discovered in [illegible] Java in 1821; cranial capacity about 62% of man and nearly twice that [illegible]. Possessed articulate speech. Stature 5 ft. 8 inches. Not in direct line of human descent. Early Pleistocene (Pre-Palaeolithic) ½ million year ago. D. [illegible] *Eoanthropus dawsoni*. Discovered in 1912 from Thames gravel at Pilt[illegible], England. Cranial wall very thick, brain nearly human. Not in the [illegible] line of human descent. Lower Palaeolithic of the Pleistocene nealy ½ [illegible]. (*Original photographs of plaster models of reconstructions in a wall [illegible] the Zoology Museum, St John's College, Agra*).

Eoanthropus dawsoni or the Piltdown man (Fig. 445) was nearly as old as Java man. Fragments of skull, mandibles, a few teeth were discovered

in Sussex (England) along with flint instruments and 16" tool of bone of an extinct elephant.

Homo neandertalensis or the Neandertal man (Fig. 446) was definitely human. He had large face, protuding jaws and somewhat stooping gait Knew the use of stone implements. He flourished in Asia and Europe about quarter of a million year ago.

Fig. 446. Extinct men. Continuation of fig. 445. A. Neandertal man *Homo neandertalensis*. Discovered near Dusseldorf, Germany in 1856. Brain human, chest large, knee bent, stooping and stocky build. Stature 5 ft. Slow moving. Interglacial Pleistocene, ¼ million year ago. B. Cro-magnon man *Homo sapiens*. Discovered at Gower (Wales) and Aurignac (France) in 1852. Later 2 skeletons unearthed at Cro-magnon (France) in 1868. Stature erect. 6 ft. male, 5 ft. female. Swift footed. (Original photographs of plastic models of reconstructions in a wall case in the Zoology Museum St. John's College, Agra).

Homo sapiens fossilis or the Cro-magnon man (Fig 446) lived in caves about 40,000 years ago. He fashioned stone implements, carved on bones and painted on the cave walls.

Fossil [illegible] : 1. *Palaeoanthropus heidelbergensis* known by a lower jaw from Heidelberg [illegible]; 2. *Plesianthropus transvaalensis*; 3. *Telanthropus capensis* [illegible] 4. *Paranthropus robustus* and 5. *Paranthropus crassidens* discovered [illegible] and 6. *Homo soloensis* from Java. Not all of them are in the direct line [illegible] modern man.

The modern man *Homo sapiens* appeared after the Cro-magnon race. The cradle of the modern race was in Central Asia, whence man spread everywhere. Early man was undoubtedly a *hunter* but also gathered wild fruit and roots. Later he became a *food producer* and domesticated animals and cultivated plants. He is an enemy of practically every other animal in the world. The only animal that he possibly befriended at an early period

was the dog. He differs from all other animals in his unnecessarily and abnormally over-developed brain—he is at once distinguished from the rest of the Primates by his "swollen head".

Résumé

1. The Anthropoid apes are arboreal mammals without tail and cheek pouches. They include the gibbons, orangutans, chimpanzees and gorillas.

2. Man is characterized by erect posture, ability to articulate words and by generalized dentition.

3. All the human beings living at present belong to a single species *Homo sapiens*, subdivided into various races, *viz.*, Negroid, Caucasoid and Mongoloid.

4 Man is of very recent origin. The earth is estimated to be 3350 million years old but man appeared hardly a million year ago. Several fossil species of man are known, *e.g.*, *Pithecanthropus erectus*, *Homo neandertalensis*, etc.

CHAPTER XXV

GENERAL PRINCIPLES OF BIOLOGY

1. ANIMAL ECOLOGY

Fundamental principles of ecology.—ANIMAL ECOLOGY (*oikos*= house) deals with the interrelations of animals and ***environment*** or their surroundings. It is essentially a study of the animal in its house.

Not only animals and plants are interdependent but every animal is also linked with every other animal in some way or other. It affects other animals either for good or for bad and is in turn affected by them. Furthermore, organisms are not only influenced by their nonliving surroundings, but they also act on the latter. The vegetation of a region, for example, is determined largely by its climate, topography, etc. The vegetation at the same time exerts its own influence on the climate, configuration and fauna of the region. Organisms are not thus isolated entities but form an *integrated part* of the whole. *Not only all life is one but life itself is a part of Nature.* The fundamental principle that underlies animal ecology therefore is : *Every animal is a part of the environment*; it is a member of Nature, in which it plays a definite role. An animal and its environment are mutually interactive and adjustable.

The interrelations between animals and their environment are very complex. These interrelations show two naturally opposing tendencies : 1. infinite increase of the animal on the one hand and 2. total annihilation on the other hand. The resultant of these two mutually opposing, interacting and adjustable tendencies is the animal. This resultant is a dynamic equilibrium between the favourable and unfavourable influences. There is thus a *balance of Nature*, which possesses in itself the power of automatic readjustment if the equilibrium is disturbed. The environmental influences that interact with the animal constitute ***ecological factors***.

Analysis of ecological factors.—The ecological factors are of the following kinds :

1. Physiographical, or ***abiotic*** or inorganic factors
2. Biocönetic, ***biotic*** or organic factors and
3. Superorganic factors due to the influence of the intelligence of human activities.

The abiotic factors arise from the nonliving environment and comprise climatic or geographical and local influences. Climate depends upon latitude and altitude. It is determined by temperature, humidity, rainfall, light, pressure of atmosphere, wind, composition of air, atmospheric electricity, etc. The local factors originate from differences of location such as nearness to water, shelter, mechanical layering and structure of soil, presence of insurmountable barriers like high mountains, seas, slopes, etc., and currents and torrents

Biotic factors emanate from the living environment or ***biocönesis*** as it is collectively called. It includes the conditions of nutrition, reproduction, social relations to foreign organisms, natural enemies, etc.

As long as the ecological factors remain at the same average, the density of population and thus the composition of the biocönesis do not fluctuate far from the mean permanently. Such a state is called ***stability***. Changes in the ecological factors necessarily cause changes in the biocönesis also. Such changes in the biocönesis constitute ***succession***. With the stabilizing of the factors once more succession leads to an end stage representing the true biocönesis of the locality, a condition called ***climax*** or ***Schlussverein***.

The superorganic factors emanate from the activities of human beings. Deforestation, monoculture (growing one kind of plant or "crop"), draining of marshes, pollution of rivers by city and industrial wastes are some of the examples of the effects of civilization. The topography and climate of a region are fundamentally changed by human activities.

The various ecological factors act on the animal not only separately but the sum total of all the factors itself forms a factor. For each ecological factor there is a ***minimum*** or ***threshold value***, below which the animal cannot exist. If the factor increases, an ***optimum*** can be reached when the conditions are most favourable for the animal. The factor can increase still further and reach a ***maximum*** or ***upper vital limit*** beyond which again the existence capacity is lost. ***Ecological valence*** of the animal is the amplitude between the minimum and maximum factors within which life is possible. The effect of the ecological factors is perceived in changes in the ***population density*** of an animal. Population density is expressed by the number of individuals of all stages of the animal in unit space. The effect is also measured by the total metabolism, e. g., growth or development in the animal.

Relations with the Nonliving Environment

TEMPERATURE.—Temperature is the most important of the abiotic factors. The temperature valence of animals is not very wide. The upper vital temperature does not exceed 50°C. Some Protozoa can withstand an exposure to 54°C but most metazoa cannot bear more than 45° C. At 60°C protoplasm coagulates and it is the highest fatal point in most cases. A few hardy insects like *Rhizopertha dominica*, that feeds on stored grains, can bear exposure to 62·5 C for fifteen minutes. Some mantids live on bare ground in Palestine deserts at a temperature of 62°C. Hibernating animals survive a temperature of 50°C but in most cases development ceases at −10°C.

Warm-blooded animals like birds and mammals are not directly affected by changes of temperature to a marked degree. Many like birds migrate but others like the polar bear hibernate. The cold-blooded fishes, amphibians, reptiles and all invertebrates are directly influenced by even slight changes of external temperature. These grow and feed in warm weather but hibernate during the winter. Besides having a direct influence on the metabolism and development of organisms, temperature affects other ecological factors, such as moisture content and movement of air, pressure of gases, etc., and through them indirectly the organisms.

Changes of temperature have far-reaching influence on the metabolism of animals. The total metabolism, measured in terms of development and plotted on a graph as the reciprocal of the time is straight under ordinary temperatures. Both at very low and high temperatures, generally below 10 C and 35 C respectively, the curve bends. This bending of the temperature-development curve indicates a slowing of the development at these extremes of temperature. The temperature zone at which the line is straight is the ***effective temperature*** of development. The ***minimum effective temperature*** is the ***threshold of development*** at which the development just begins and the ***upper vital limit*** is the ***maximum effective temperature***, at which the development just ceases. Temperatures immediately above the upper vital limit and below the threshold value are ***zones of inactivity***, from which the animal can however recover.

The ***vital temperature maximum*** is the *highest* temperature at which an animal can still live. It is different for different animals and in the same species depends upon the following : 1. Duration of the action of the temperature, 2. The state of general metabolism, 3. The state of nutrition and the nature of feeding in the course of the exposure to the temperature, 4. Humidity (dry heat desiccates the body more rapidly than moist

heat), 5. Thermal conductivity of the body and 6. Size of the animal. The ***vital temperature minimum*** is the *lowest* temperature at which an animal can still live. It depends on 1. the rate of cooling, 2. the state of metabolism, 3. previous experience of the animal to low temperatures and 4. the duration of the low temperature. Further beyond these points are the ***fatal temperatures.***

Various attempts have been made to elucidate the relation between temperature and animal metabolism. The effect of temperature on the duration of development is, for example, expressed by the ***catenary curve*** formula

$$y=\frac{m}{2}(a^x+a^{-x})$$

drawn with the critical temperature as the zero point, in which $y=$ duration of development, $x=$ the temperature in degrees counted from the critical point, $m=$ the minimum duration of development at the critical point and $a=$a constant that determines whether the development is accelerated or retarded. Since the ***velocity*** (rate) ***of development*** is the reciprocal of the duration of development, the relation

$$\frac{1}{y}=\frac{m}{2}(a^x+a^{-x})$$

also holds good.

According to a German scientist JANISCH, the relation between temperature and biological activities is of the nature of an ***exponential function.*** The temperature changes and the fluctuations of biological activities can be graphically expressed as a simple ***exponential curve.*** It has recently been shown that this ***exponential law*** holds good not only for temperature but also for all ecological factors and for all biological activities.

HUMIDITY AND RAINFALL.—Next to temperature the water relation of animals is the most important. Many animals like the Amphibians cannot exist in the absence of abundance of moisture and water. Others like the rice weevil (insect), *Sitophilus oryzae*, can develop happily in grain with only 10% of moisture. Rainfall is dependent on air humidity. The abundance of animals is determined not only by the total rainfall of the area but also by its distribution in the year.

PRESSURE.—Pressure has an important effect on animals. Animals that inhabit the sea level are normally under higher pressure than those on the mountains. The influence of pressure is very great on marine animals. The pressure in the great sea bottoms often exceeds two and a half tons per square inch or over one thousand times that on the surface.

WIND.—Wind is largely determined by temperature and pressure. Storms often uproot trees and destroy the abodes of animals. Wind current frequently transports small insects over wide areas.

LIGHT.—Light affects the activities of animals in diverse ways. The usual effect of light is stimulating. Light is also the greatest single source of energy for all organisms. The photosynthetic activity of plants actually bottles up the sunshine for the benefit of animals. Many animals are active only in bright sunshine. Bees and butterflies for example do not fly even if a passing cloud obscures the sun.

Clima.—The sum total of these meteorological conditions that determines the average state of the atmosphere at any place constitutes ***clima*** or climate. From the standpoint of the biologist, clima is the combination of the various conditions of the atmosphere and topography of the earth's surface, that determines the suitability of a region for the life and health of an animal.

Besides the general classification of clima into the temperate, subtropical, tropical and arctic, we have also the following :—

1. CONTINENTAL CLIMA : Warm summer and cold winter. Humidity slight in summer but great in winter. Evaporation rapid. Great diurnal and annual temperature fluctuations, that are also irregular. Little cloudiness. Winds weak.

2. OCEANIC CLIMA : Cool summer and warm winter. Great humidity, heavy precipitation of water, especially in winter. Diurnal and annual temperature fluctuations slight. Heavy clouds. Strong winds.

3. COASTAL CLIMA : Summer relatively warm and dry. Conditions reverse in winter. Sea and land breezes.

4. MOUNTAIN CLIMA : For each increase of 100 metre elevation above the sea level the temperature falls by an average of 0.5° C. Summer warm. Temperature fluctuations highly irregular but slight. Radiation strong, especially the ultraviolet rays of the sunlight. Reflection (glare) of sunlight from the snow. Reduction of atmospheric pressure becomes perceptible only above heights of 3000 metres. Rainfall frequent and heavy.

5. VALLEY CLIMA : Great temperature extremes with frost at night. Air stagnation (absence of wind). High humidity.

6. HILL SLOPES CLIMA : Temperature extremes moderated. No stagnation of air. Southern slopes (in the northern hemisphere) at higher latitudes warmer than the northern slopes.

7. FOREST CLIMA : Slight diurnal temperature extremes. In the tropical forest high humidity in summer. Frequent and heavy rains. Wind

screened off by trees. Deforestation reduces rain and increases temperature fluctuations.

8. DESERT CLIMA: Dryness and rapid diurnal heating and cooling. Strong seasonal temperature changes. Local dust storms.

9. RIVER VALLEY CLIMA: Weak temperature extremes. High humidity. Frequent clouds. Less thunderstorms. Air stagnation.

RELATIONS WITH THE LIVING ENVIRONMENT

The living environment of an animal is composed of 1. other individuals of the same species, 2. individuals of other species of animals and 3. of plants. The relations of the animal with the biotic environment are thus both ***intraspecific*** and ***interspecific***. These relations may be beneficial or harmful to the animal.

Intraspecific relations

In intraspecific relations we deal with the association of the individuals of the same species or ***homotypic association*** as it is called. The individuals of a species of animal often live together and require the same kind of environmental conditions. Over-crowding often results and leads to ***concurrence*** or keen struggle for the same food, living space, mates, etc. When concurrence becomes acute, many of the weaker individuals naturally succumb. Carnivorous animals often develop *cannibalistic* tendecnies and start eliminating their younger or weaker brethren. Young frogs, for example, are devoured by older frogs. The young of the praying mantids devour each other till ultimately only one or two out of the several hundred survive.

Intraspecific relations are more frequently beneficial to the animal. Herding of cattle, hunting in packs by wolves, jackals, etc., association of the sexes, care of the parents for their offspring and social life are intraspecific relations that are beneficial to the animal

Associations of the sexes.—The association of the sexes is temporary or enduring and includes courtship and marriage. In the majority of animals the association of the male and female lasts only for the breeding season. In many animals however the two sexes live together year after year and bring forth several generations of offspring. Tigers are, for example, monogamous. In some animals the association of the sexes ends in a peculiar permanent marriage. The husband is pinned on to the apron-strings of his better half, on whom he is a total parasite. Among many worms the male is usually carried about and nourished by the female.

The male of the fish *Photocorynus* (Fig. 447) is a degenerate dwarf who is permanently attached to the head of the female. He has no independent existence and to him marriage literally means self-effacement and complete subjugation to his wife.

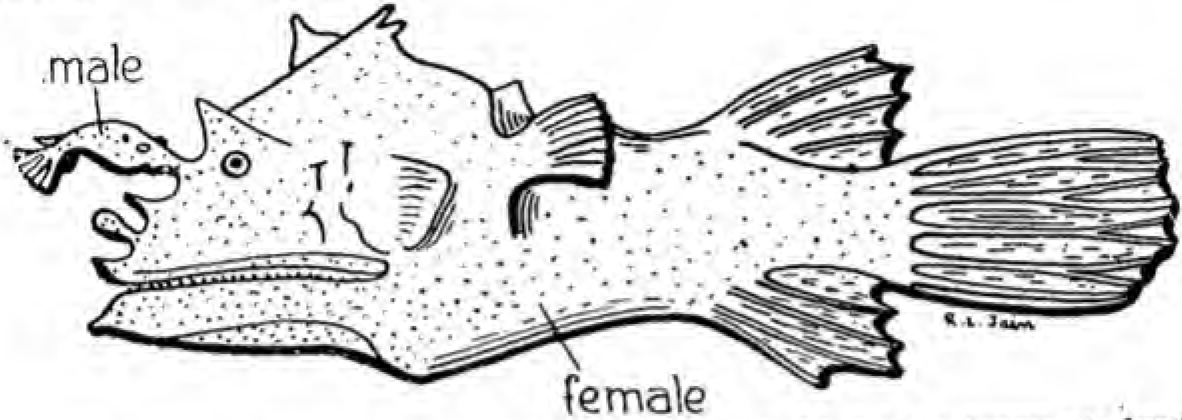


FIG. 447. *Photocorynus spiniceps*. The male of this fish is a degenarate dwarf that is a permanent parasite attached to his giant wife. (*From Tate Regan*).

There is usually some sort of courtship and selection of the mate. Courtship is often accompanied by display, song and fight. Production of light, sound or display of gorgeous colours and of valour are usually gifts of the male. Male frogs engage in their familiar concerts during the breeding season and also indulge in free fight among themselves. Male scorpions

FIG. 448 Parental care in insects. The female earwig stands guard over her cluster of eggs laid in an underground chamber. She picks up and licks her eggs clean. The female water bug lays eggs on the back of the male, who carries them till the young hatch.

similarly fight and kill each other until only one survives as the lucky suitor for the hand of the Miss Scorpion. Courtship is developed to a very high degree among birds.

Parental care.—The immature stages of animals are exposed to dangers more than adults. Only a very small fraction of the total number of offspring actually survives and even this is due solely to the protective care of the parents. *Parental care includes all the activities of an animal which are in the interest of its offspring.* It aims at securing optimum conditions for the eggs, larvae or other immature forms, shielding them from unfavourable climatic factors and protecting them from the attack of natural enemies. Two more or less distinct stages of development of the parental care are recognized: ***Brutfürsorge*** and ***Brutpflege.*** Brutfürsorge (pronounced *brootfuerzorgay*) comprises care for the young up to the point of providing them with proper shelter and optimum conditions. In addition to these precautionary measures, if the parents directly guard, nurse, carry and tend the young, we speak of Brutpflege (pronounced *brootpflaygay*).

Most animals resort to concealment of their eggs as a precaution against unfavourable environment. Turtles for example bury their eggs underground Cockroaches and bedbugs conceal them in crevices or other suitable holes. Others like spiders and praying mantids prepare elaborate egg packets of silk or other material and carefully hide them under stones, dirt or leaves. A number of animals construct more or less elaborate nurseries and store them with food for the future offspring, which they will never see. The common potter wasp, *Eumenes*, for example (Fig. 449) builds beautiful cells of clay. Moist clay pellets are transferred to a suitable place and worked layer by layer into a pot-shaped structure. She then suspends an egg from the roof of the cell. She now sallies forth to hunt for green caterpillars, which she paralyzes by stinging. The stung caterpillars are thurst into the mud cell, which she now seals with clay. The mother wasp dies after her labours of building and provisioning for her children. When the larvae hatch from the eggs they find themselves provided with living but paralized meat ready for food.

The habit of watching and standing guard over the eggs or brooding over them is extremely common among animals. The common earwig (Fig. 448) for example, lays her cluster of eggs in an underground chamber, which she excavates. She stands guard over her eggs, hides them under her body, now and then picks up an egg and licks it clean and generally behaves much like a brooding hen. A number of animals like the prawn, spider, etc. carry their eggs with them until the young are hatched. Still others like the sea-horse (Fig. 313), water bugs (Fig. 448), midwife toads, etc., compel the males to carry the eggs. Honey bees,

FIG. 449. Parental care. A. The potter wasp constructs clay cells, lays an egg in each and stores them with the caterpillars paralyzed by her sting. B. The paper comb of social wasp in which the young are reared.

ants, social wasps, termites, birds, monkeys and apes live in families, guard, feed, nurse and educate their young. Some like the koil and cuckoo wasp smuggle their eggs into the nurseries of others, who act as foster parents.

Interspecific Relations

Interspecific association of animals is extremely varied. It is an association of many different kinds of animals and is distinguished as ***heterotypic association***.

FIG. 450 Acorn barnacles growing on the shell of *Mytilus* a mollusc. An example of epizoism. Neither the barnacle nor the *Mytilus* is injured or benefited by this association.

The ***epizoic*** association is the simplest of all the interspecific relations. One animal lives upon another without inconvenience, harm or benefit to the latter. Many colonial hydroids that normally grow attached to rocks often grow on shells of Mollusca. Crustacea like the acorn barnacle (Fig. 450), that are normally attached to submerged timber or rocks, often live upon molluscan shell.

In ***commensalism*** the epizoic association of one species with another benefits one but neither harms nor benefits the other. The word commensalism literally means eating at the same table and was originally employed under the belief that one animal used bits of food, dropped off by the other. It includes associations other than those concerned with feeding. The small sucker fish *Remora* fastens itself to the body of shark and

secures transportation. Several hydroids grow on the back of crabs and thus secure wider range of forage.

If commensalism involves the mutual benefit of the two different animals that associate, we have ***mutualism***. Sea-anemones (Fig. 451), are often attached to molluscan shells that contain hermit crabs. The crab is protected from its natural enemies by the nematocysts of the

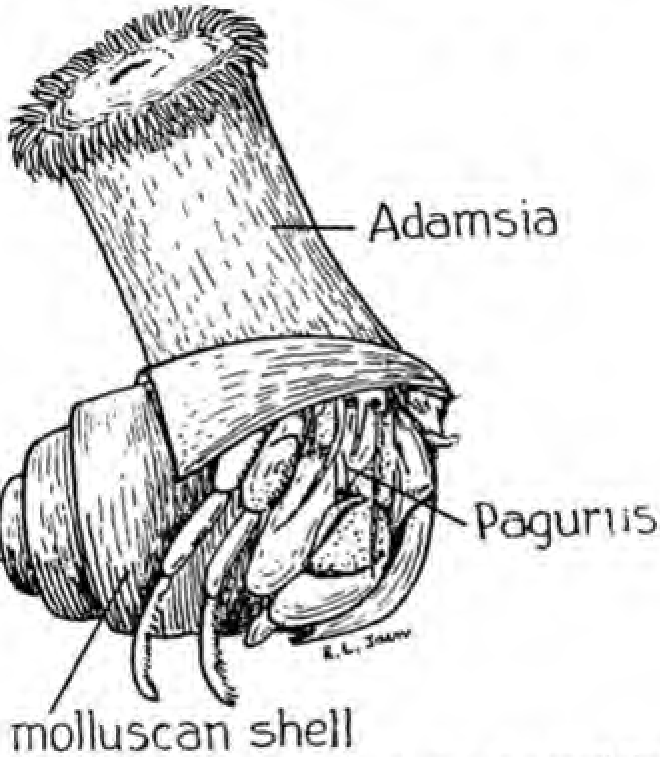


Fig. 451. Mutualism. *Pagurus*, the hermit crab in a snail shell that also bears a sea anemone. The crab benefits by being protected by the nematocysts of the sea anemone, and being a slow eater, drops off bits of food to the anemone.

sea anemone. Being a slovenly feeder, the crab drops off bits of food that is greedily utilized by the sea-anemone. Certain birds enter the gaping mouths of crocodile, pick off leeches and morsels of food from between the teeth of the reptile. The latter is thus relieved of the blood-sucking parasites.

In ***symbiosis*** two species live together in very close association to mutual advantage and separate life is impossible. Certain Protozoa are ***symbionts*** in the gut of termites. The protozoa digest the ingested wood for the benefit of themselves and for the insect. Termites cannot use their food in the absence of the Protozoa, which also can exist only in termites.

Slavery is a specialized case of symbiosis. It is met with between ants and aphids or cowbugs (Fig. 452). The ants provide shelter and

also protect the aphids and cow bugs. The latter produce secretions that constitute the food of ants. The aphids, cowbugs and ants can however also live independently. The association is not obligatory as in symbiosis.

FIG. 452. Slavery between ants and membracid bugs.

Predatism is the relation between a hunter and the hunted. A ***predator*** hunts its prey for food. The beneficiary is the predator and the prey is destroyed. Most carnivorous animals that feed on live prey are predators. The frog is predacious on worms, flies and other smaller animals. The snake is a predator on frogs and rats. The tiger and lion are also predators. The praying mantid that kills other insects, the solitary wasp that hunts for caterpillars for provisioning its nursery

and birds like the owl that devour rats are other examples. A predator is larger, stronger and more cunning than its prey.

Parasitism is an interspecific association in which the benefit is all one-sided and is at the cost of the other. A parasite lives in or on the body of its ***host*** more or less permanently. A parasite is always smaller than its host. It secures shelter, protection and food from its host but gives nothing to it in return. It is mostly incapable of independent existence but the host can live apart. Parasitism differs from predation in that a predator kills the prey outright, but a parasite usually avoids killing the prey and only feeds on the living substance unobtrusively. A predator "spends the capital" but a parasite takes only the "interest" on the capital! A parasite attacks only one host species or it may frequently live in two or more hosts. In the latter case it has one ***definitive*** and several ***intermediate*** hosts, as for example, in the case of the malarial parasite, liverfluke and tapeworm. The peculiar association of the sexes in the fish *Photocorynus* described above and the dependence of the foetus on the mother in mammals do not constitute parasitism. In parasitism two animals of different species or unrelated groups are concerned. It is essentially an interspecific, not intraspecific relation.

Temporary parasites lead a free life for some time. ***Permanent*** parasites are incapable of free life, except rarely as very early larvae. ***Obligatory*** parasites have no life apart from the host but ***facultative*** parasites may live so. ***Ectoparasites*** such as leeches, bedbugs, lice, etc., live on the surface of the host. ***Endoparasites*** like liverfluke, tapeworm, malarial parasite, ascaris, hookworm, etc., live within the body of their hosts. A parasite itself is very often attacked by a ***hyperparasite*** *Nosema*, a protozoan, is for example, a hyperparasite that attacks the liverfluke. The cercariae of *Cotylurus* parasitize the rediae of the liverfluke. It is a case of robber being robbed of his ill gotten gains! Truly the poet little realized the full truth when he sang:

"Great fleas have little fleas upon their backs to bite 'em,
And little fleas have lesser fleas and so ad infinitum.
And the great fleas themselves, in turn, have greater fleas to go on
While these again have greater still, and greater still, and so on."

In ***brood parasitism*** the animal shifts the burden of incubating its eggs and nourishing the young on the foster parent, as for example, the koil and the cuckoo wasp.

Some parasites have little or no effect on their hosts. Others often injure their hosts temporarily or permanently by destroying their tissues, producing toxins and transmitting ***pathogenic*** (= disease producing) germs.

The parasitic mode of life frequently leads to more or less pronounced organic degeneration, such as reduction of the organs of locomotion, special senses, alimentary canal, etc., and excessive development of the organs of reproduction.

Parasitism is met with in all groups of animals : Protozoa, Coelenterata, Platyhelminthes, Nemathelminthes, Annelida, Crustacea, Arachnida and Insecta. It is often not easy to distinguish between predatism and parasitism. Predatism and parasitism are the normal features of the Animal Kingdom ; every animal is essentially a parasite – a robber.

Mimicry is an interspecific association, in which one animal is protected from its natural enemies by its bitter taste, foul smell or in some other way. Another animal not so protected, not only lives together but also resembles the protected species, for which it is mistaken by the enemy (*vide* under Adaptations).

Myrmecophily is the association of various kinds of insects, spiders, etc., with ants. Several of beetles, butterflies, wasps, crickets and flies habitually inhabit the nests of ants. Some of them are treated as guests by the ants, others are trespassers and interlopers into the privacy of the ants. A few are playful pets that brighten the monotony of an ant's existence.

Relations to Man

The interspecific relation between man and other animals is a sad tale; it is a record, of which man cannot be proud.

Man has brought ruin and death to countless animals. He has driven many from their age-old homes, pilfered their food and other hard-earned possessions or has deprived them of their legitimate due. He has also enslaved (domesticated) many and has exterminated hundreds. The only animal that ever befriended him is the dog, whose friendship he has systematically abused. No doubt he may be said to have helped a few animals here and there but with selfish motives. Perhaps in this unequal fight against superior cerebral powers the insects are the only animals that have successfully managed to maintain their own and even gain an upper hand. From the point of view of other animals, man is thus a *total enemy*.

From the standpoint of man however, animals can be roughly grouped into the following four categories : 1. injurious, 2. beneficial, 3. useful and 4. indifferent.

Animals, which by their structure or habits of life, interfere with some desired object of man are described as ***injurious*** or harmful. Some are *directly* injurious, because they hinder production of human food or because they cause disease and death of man. Such are for example the pathogenic Protozoa, Platyhelminthes and Nemathelminthes ; crop pests like locusts, grasshoppers and caterpillars ; disease carrying insects like flies, fleas, lice, bugs, mosquitoes, etc. The *indirectly* injurious species work against those animals that are either useful or are beneficial to man. They are the concurrents, predators and parasites of our domesticated animals. They also include the carnivorous wild beasts, mites, ticks, worms, etc., that attack cattle, sheep, goat, horse and other useful animals. The Protozoan *Babesia* that causes the Texes fever in cattle and *Nosema* that gives rise to the pebrine disease of the silkworm are other examples. Some animals like the ants favour the development of insects such as aphids and mealy bugs injurious to agriculture and horticulture and are therefore indirectly injurious *These are friends of our enemies.*

Beneficial animals advance the interest of man, either directly or indirectly. Pollinators of crops and fruit trees, for example, the honey bees, butterflies, moths, certain humming birds, etc., are directly beneficial to us. Others like the earthworms that improve the condition of the soil are also directly beneficial. Indirectly beneficial are those animals which are harmful to the injurious forms or favour the useful and beneficial ones. *They are enemies of our enemies.* The common owl for example is of great indirect benefit to man because it destroys vermin. Numerous snakes that destroy rats also come under this category. Certain ants like *Camponotus* or the carpenter ant, that often colonize in dead wood and thus prevent the attack of termites, are highly but indirectly beneficial. Insect predators and parasites of insect pests and insectivorous birds like the myna are other familiar examples. Frogs should also be considered as indirectly beneficial, because they devour large numbers of harmful insects.

Useful animals are directly useful to man ; they produce useful products like meat, milk, wool, hides, ivory, fats, oils, honey, silk, lac, dyes, ornaments and medicines. The list of useful animals is very long and includes examples from practically every phylum : Porifera (sponges), Coelenterata (corals as medicine and ornaments), Mollusca (food, medicine, money, ornaments like buttons, rings, pearls), Arthropoda (food : prawns,

grubs, honey ; clothing : silk ; medicine : cantharidin), Echinodermata (food), Chordata (food : fish, meat, eggs, milk, oil, fat ; clothing : wool, fur, hides ; beasts of burden and draught animals : horse, donkey, oxen, camel, etc).

Indifferent animals include those species that neither harm not benefit man. The vast majority of the wild and marine animals belong to this category.

The grouping of animals in these four categories is *arbitrary*. It has its full limitations. The grouping is not also absolute : what is useful at one place may be useless or even harmful elsewhere and at other times. The cockroach that is useful to the Chinese in making curries and teas is, for example, a positive nuisance in this country. The grouping is thus a *useful fiction*, a simplified hypothesis, inaccurate but necessary in theory and practice.

Relations to Plants

Plant as enemy of animal.—Numerous bacteria and many true fungi are parasitic on various animals including man. They cause various diseases like cholera, bubonic plague, tuberculosis, etc. *Empusa musci* is a fungus that is a common parasite of flies. Insectivorous plants like venus' fly trap, *Drosera, Utricularia, Nepanthes*, etc., have developed mechanisms for enticing, capturing and digesting small animals.

Animal as enemy of plant.—Most animals are enemies of plants. Some of the minute vegetable organisms like bacteria and algae are engulfed by amoebae or are devoured by paramecia, small crustacea, insect larvae, fishes, tadpoles, whales, and other animals. The higher plants are destroyed by all classes of phytophagous animals. Insects injure plants by eating leaves, tunnelling the stems, flowers, fruits and seeds or by sucking the sap. Birds, cattle, horse, elephants and other herbivorous beasts depend wholly on plants for their food All animals are either directly or indirectly dependent on plants for food and in many cases for shelter and covering (clothing).

Mutualism Between plants and animals.—The interrelation between flowering plants, bees, moths, butterflies and other flower visitors is a special case of phytophagy. The insects seek the plants for food and at the same time benefit the plants by cross-pollinating their flowers. The plants and flower visiting insects are frequently mutually completely dependent. Some humming birds that visit flowers for nectar similarly help in cross-pollination. Birds that swallow fruits help in the dispersal of seeds. The seeds of the common *neem* tree are dispersed by crows that swallow the

fruits and eject the seeds with their droppings. *Ficus* is also similarly dispersed by the common *myna*. Numerous other animals also aid in the dispersal of barbed, hooked or thorny fruits and seeds.

Symbiosis between plants and animals.—Some of the lower plants like algae and fungi are in symbiotic relation with various animals. Certain algae that grow on the long fur of the South American two-toed sloth, *Choloepus didactylus* (Fig. 382), give the animal a green colour and make it very inconspicuous to its enemies up in the foliage. Algae that grow within *Chlorohydra* (vide page 224) are also examples of symbiosis. The algae provide the oxygen needed by the hydra and help the latter by removing the carbon dioxide. In its turn the hydra provides shelter and nutrient solutions to the algae. Ants and termites cultivate certain fungi on specially prepared nutrient media. The fungus serves as food for these animals. Other fungi like *Saccharomycetes* and bacteria live as symbionts within animals, benefit them by digesting their food for them and also derive benefit for themselves by way of shelter and nourishment. Some of the symbiotic plants manufacture the vitamins needed by animals.

Animals in health and disease.—An animal that is in perfect adjustment to its environment can theoretically carry on the vital activities with maximum degree of ease and efficiency. It is then in a state of ***ideal health.*** Such perfect adjustment between the animal and its environment is rarely if ever met with. Ordinarily ***health*** is the condition of the animal in which it can carry on its bodily functions in a normal way, though the maximum efficiency may not be attained. ***Disease*** is any interference or disturbance of this normal functional activity.

The conditions necessary for the maintenance of health include 1. proper kinds and amounts of *food*, 2. maintenance of *normal metabolism*, 3. prompt and complete *elimination of metabolic wastes* and 4. proper physical environment.

Diseases are caused by 1. inadequate living conditions involving improper rest, metabolism, elimination, environment, etc., 2. deficiency in foods such as lack of vitamins, certain minerals, etc., 3. abnormal endocrine activity like underproduction of pituitary or thyreoid harmones, 4. detrimental habits such as indulgence in alcohol, 5. inheritance as in the case of feeble-mindedness, deafness, etc. and 6. infective organisms as in the case of malaria, dysentry, yellow fever, etc.

All animals have in them the power of automatic re-adjustment and self regulation that soon restores health, even though no assistance is given from outside. Many Protozoa for example resort to encystment if changed

conditions disturb their health. An ***antitoxin*** is often produced within the body to neutralize and counteract the toxin that causes a disease. ***Phagocytosis*** or engulfing of pathogenic agents by the white blood corpuscles is another method by which the body of an animal fights diseases. Most animals develop ***immunity*** to a disease by building up a power of resistance to subsequent attacks. A physician does not really cure a disease but he may merely help the body to cure the disease.

Animal behaviour.—The sum total of an animal's movements constitutes its behaviour. The basis of animal behaviour is irritability or the capicity to respond to stimuli. The ***innate patterns*** of ***behaviour*** comprise 1. tropisms, 2. reflexes and 3. instincts. ***Tropism*** is the simplest behaviour and involves response by the same cell that receives the stimulus. It is the most invariable mechanism of responses to the environmental influences and is not dependent on the nervous system. It includes reflex movements of an animal away from or towards a stimulus. ***Reflexes*** are automatic, involuntary movements, in which at least two neurons are necessary. They constitute the simplest of the invariable but co-ordinated responses. A series of co-ordinated reflexes constitute an ***instinctive*** action. It is really an inherited habit—a complex and invariable form of behaviour. With many animals the choice of food is an instinctive act. Migration of birds and the care for the young in animals are also largely instinctive. A ***habit*** is a form of behaviour acquired as a result of repeated action. It involves an individual modification of behaviour on the basis of previous experience. ***Memory*** is due to persistance of some modification in a nerve cell brought about by a stimulus. The effect of a stimulus persists longer than the stimulus itself. Frequent repetition of the stimulus increases this persistance. Ability to learn by experience constitutes ***intelligence***. Display of intelligence includes modification of the patterns of bahaviour in adaptation to special needs. All animals, from amoeba to man, possess it in varying degree, depending upon the speed of learning. ***Reasoning*** surpasses intelligence and involves the ability to form abstract ideas that guide the actions of the animal. No sharp line of demarkation can be drawn between the various types of animal response. The differences are only of degree and not of quality. Amoeba, hydra and earthworm learn after several hundred experiences, the dog and man may learn after a few. The process of learning is the same in all of them.

2. ANIMALS IN THEIR HAUNTS

Animals are found on the earth's surface everywhere to which access is possible. The craters of active volcanoes, recent lava, Dead sea

and the bottom of the Black sea are devoid of animals. Life is sparse on the sandy wastes but not absent.

The particular locality in which an animal lives is its ***habitat.*** All animals that inhabit any given place comprise a ***community.*** A pond for example is a community of aquatic animals. Within this community there are lesser environments like the surface, the shore and the deep water, each with its own peculiar animals.

Animal haunts comprise 1. salt waters, 2. fresh-water and 3. land.

Marine animals.—Salt waters include the oceans, seas, salt lakes, etc., that constitute about 71% of the surface of the earth. They provide extensive and stable habitats. Their physical features include uniformity of temperature, salinity, increase of pressure with depth and total darkness beyond a depth of 3000 feet. The environments provided by the seas comprise 1. the open sea, 2. the deep sea and 3. sea shore. Marine animals include the following :

1. ***Plankton*** or animals that float and are passively carried by currents. They are mostly microscopic forms, such as Protozoa, Crustacea, etc.

2. ***Nekton*** comprise the animals that actively swim about, such as medusae, jelly-fishes, fishes, sea snakes, turtles, birds, whales, etc.

The plankton and nekton constitute the ***pelagic*** or open surface sea fauna. Thay have plenty of room, sunshine and inexhaustible food. Many pelagic animals are transparent and phosphorescent.

3. ***Benthos*** are bottom dwelling animals that are subdivided as :

(*a*) ***Littoral*** or shore forms. The sea shore offers very stimulating environments. Ebb and flow of the tides, fresh-water floods, desiccation, alternation of night and day, waves, etc., characterize the sea shore. Animals are most abundant on the sea shore. Littoral fauna include Infusoria, Foraminifera, sea-anemones, crabs, sea-urchins, acorn and goose barnacles (Fig. 221), sea spiders (Fig. 213), Gastropoda, sea-squirts and numerous birds.

(*b*) ***Neritic*** compose the animals that live below the tide mark, up to about a depth of 100 fathoms on the continental shelf. Protozoa to fishes compose the neritic fauna.

(*c*) ***Abyssal*** fauna include all the deep sea animals. The deep sea is totally dark. It is permanently quiet. Its tempearture is at 4°C and never varies. The pressure is enormous : at a depth of 2500 fathoms it exceeds two and a half tons per

square inch. The deep sea is devoid of all plant life including bacteria. The Abyssal fauna depend upon the organic debris that falls from above or feed upon one another. Most abyssal animals are small, blind or grotesque-looking forms. Some are phosphorescent. Abyssal fauna include Protozoa, sponges, corals, Crustacea, Mollusca and peculiar fishes with terrible jaws.

Fresh-water animals.—The fresh-water differs from the sea in 1. its lower salinity, 2. being scattered, 3. its lesser volume and depth and 4. its greater variability of temperature, currents, turbidity, plant growth, etc. Fresh-water occupies only 1% of the earth's surface. Often fresh-water dries up completely during summer.

Fresh-water animals include Protozoa like Amoeba, Euglena; Coelenterata like hydra; worms, snails, Crustacea, spiders, mites, insects, fishes, frogs, snakes, birds and mammals.

Fresh-waters comprise 1. running waters like streams and rivers, and 2. stagnant waters like ponds, tanks, lakes, swamps and marshes.

Terrestrial animals.—The land surface is about one-fourth that of the ocean. The ocean is everywhere inhabited but on land life exists up to 25 metres underground. Despite these limitations nearly four-fifths of the animals are terrestrial. Oxygen, light and other ecological factors are more varied on land than in water. Vital activities of terrestrial animals are therefore more intense than those of aquatic animals. The muscles of a housefly, for example, contract 330 times per second, a thing unknown in aquatic life. Terrestrial habitats include :

1. ***Tundra*** or treeless Arctic regions, where the ground thaws for very brief periods in summer. The vegetation comprises mosses, lichens, grasses and herbs. The fauna is charaterized by wolf, fox, lemmings, musk ox, reindeer, etc.

2. ***Evergreen forests*** are mountainous regions south of the tundras and are composed of pine, firs and other coniferous trees. Deer, elk, goat, red fox, bears, birds, etc. inhabit them.

3. ***Deciduous forests*** are green in summer but bare and bleak in winter. Amphibians, snakes, squirrels and birds live here.

4. ***Grasslans*** are large areas of grassy plains inhabited by bison, cattle, wolf, rabbits and birds.

5. ***Deserts*** are arid sandy or rocky areas, with scant or thorny vegetation and extremely hot in summer. Lizards, snakes, camels, lions, ostriches are denizens of deserts.

6. ***Tropical rain forests*** have abundant rainfall and warm climate. The vegetation is abundant and varied. The fauna includes insects, monkeys, bats, birds, reptiles, etc.

3 ADAPTATIONS

What is adaptation ? Every animal is more or less fitted by structure, physiology and habits to particular modes of lives or for particular habitats. There is a certain amount of harmony between the animal and its environment. Aquatic animals, for example, have stream-lined bodies that have no projecting parts. Terrestrial animals on the other hand are differently constructed. In water the animal is partly supported by the buoyancy of water and has no need for limbs, but on land the animal must support the weight of its body on its limbs. Aerial animals have wings, lightly constructed bodies and keen eye sight that enable them to fly efficiently. The fish is thus fitted by structure, physiology and habit for aquatic life ; the dog for terrestrial and the bird for aerial life. The honey bee that sucks nectar and gathers pollen from the flowers has the mouthparts modified for reaching and puncturing the nectaries and brushes on the legs for collecting pollen. When the structure, physiology and habits of an animal are in harmony with its habitat and its special mode of life, it is said to be ***adapted*** for that habitat or mode of life. ***Adaptation*** is the capacity of the animal to respond to or meet the environment in such a way that it ensures the preservation of the individual and of the race. It enables the animal to successfully exist in a particular type of habitat.

JEAN BAPTISTE DE LAMARCK (1744-1829), a French naturalist (Fig. 453), was the first to emphasize the importance of adaptations. Animals modify their response to changing environment and thus become adapted better and better. In other words the environment causes the adaptative modifications. CHARLES DARWIN (1809-1882), an English Naturalist believed that animals always vary. If some of these variations are in harmony with the environment, the animal survived, otherwise it passed out. In other words, DARWIN believed that animals are ***preadapted*** and seek suitable environment. He did not realize the influence of the environment in shaping the animal. Modern view is more and more swinging in favour of LAMARCK.

Adaptative convergence —Animals of unrelated groups that live in the same habitat and are subjected to the same environmental influences become similarly adapted. They are said to ***converge***. ***Adaptative convergence*** thus occurs amongst *unrelated* animals of the same habitat.

The aquatic vertebrates include such different forms as shark, fish, turtle, extinct reptiles like *Ichthyosaurus*, birds like penguin and mammals like seal, dolphin and whale. Aquatic mode of life requires ability to swim.

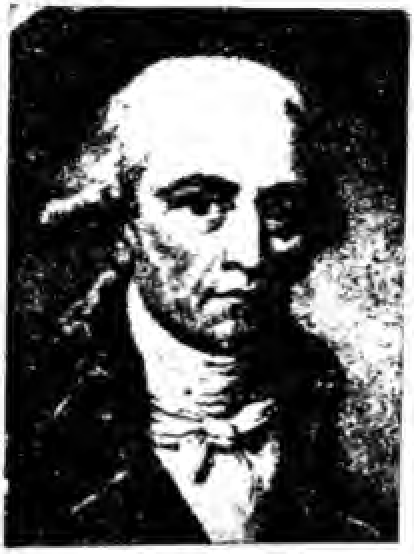


FIG. 453. Jean Baptiste Lamarck (1744-1829), was the first to propose a theory of organic evolution. (*Original photograph of a portrait in the Zoology Museum, St. John's College, Agra.*)

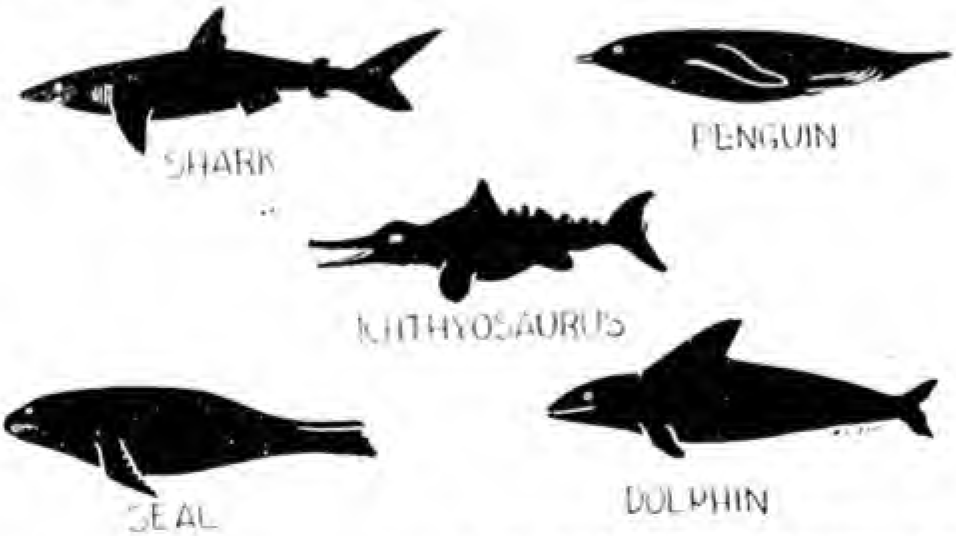


FIG. 454. Adaptative convergence in the limbs and general outline of the body in Vertebrates that live in water. The shark is primarily aquatic. The penguin, a bird has its wings modified secondarily into paddles. The *Ichthyosaurus* is an extinct reptile that took to aquatic life and had its limbs modified into paddles. Seal and dolphin are mammals that have a fish-like appearance, with paddle-like limbs. Note the general stream-lining of the body. Different classes of Vertebrates living the same mode of life have acquired the same adaptations. Their adaptations thus converge.

All these animals thus have stream-lined bodies (Fig. 454) that are torpedo-shaped and the appendages modified into paddles as adaptations for

efficient swimming. The adaptative convergence is superimposed on the fundamental differences of the classes.

Adaptative radiation.—Adaptative radiation is seen in the animals of the same class that occur in different habitats and have different modes of life like running, climbing, flying, or swimming.

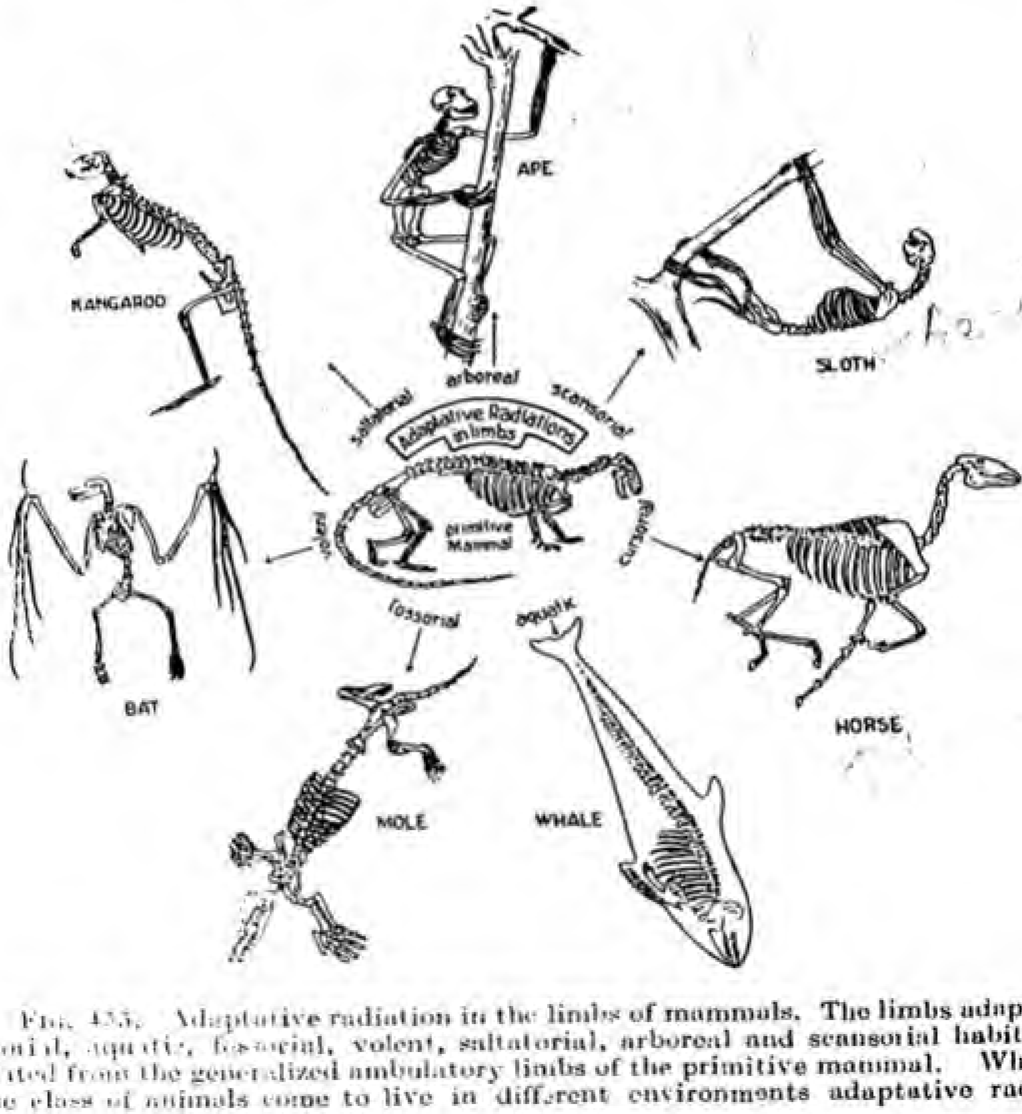


Fig. 455. Adaptative radiation in the limbs of mammals. The limbs adapted for cursorial, aquatic, fossorial, volent, saltatorial, arboreal and scansorial habits have radiated from the generalized ambulatory limbs of the primitive mammal. When the same class of animals come to live in different environments adaptative radiation results.

Some mammals inhabit forests where they cannot run. Others like the horse inhabit open plains where speed is an efficient defence. Monkeys live on trees, and must have powerful grip of the branches. Their limbs are all modified into "hands". The bat that flies has its fore limbs modified into wings. The whale that lives in the sea has its limbs reduced and changed into paddles. Thus the limbs of mammals, though built on the same fundamental plan are modified (Fig. 455) for

cursorial, fossorial, saltatorial, volent, arboreal, scansorial and aquatic modes of life.

SOME IMPORTANT ADAPTATIONS

Aquatic adaptations.—Among the numerous adaptations for an aquatic life, the more important ones include those that prevent the pelagic forms from sinking, the torrential forms being carried away and the fresh-water forms becoming diluted.

Pelagic animals are in constant danger of sinking to the bottom of the sea, where they would be crushed by the enormous pressure. In order to prevent this calamity, several surface animals keep on moving incessantly, allowing no time to sink. Others have developed various antisinking devices. The larvae of many Crustacea have long, fine feathery hairs that prevent sinking due to surface tension of water or have projecting planes. The bell-shape of the jelly-fishes is an antisinking adaptation. The sunfish, *Mola*, has an accummulation of oil for the same purpose.

Animals that inhabit mountain streams and other rapids are in danger of being carried away to the sea. Some of them overcome this by actively swimming against the current. Others develop suckers and adhesive discs, by which they attach themselves to plants or rocks.

Fresh-water is osmotically less dense than the body fluids and endosmosis thus leads to their dilution. Fresh-water animals are in a way comparable to a leaking ship, that must be constantly baled out. Many of them have impervious integument that impedes the entry of water or other devices for eliminating the excess of water. The contractile vacuoles of Protozoa are examples of such a device.

Amphibious adaptations—Most of the amphibious adaptations have been described in the case of the frog (chapter III) and Amphibia (chapter XIX). Several primarily terrestrial animals like the crocodile and the hippopotamus, have taken to aquatic or semi-aquatic modes of life. In these animals the nostrils and eyes are placed on top of the head that enables them to remain submerged just under the surface of water, with only the nostrils and eyes above.

Terrestrial adaptations.—The important terrestrial adaptations include 1. the tetrapod limbs, 2. lungs and 3. embryonal envelopes. On land the animal is not supported by the buoyancy of water but must bear its weight on limbs, which also serve for locomotion. Respiration takes place by exchange of gases in solution on respiratory surfaces. In land

animals the respiratory surface is liable to be dried up and thus prevent gaseous exchange. The respiratory organ must therefore be sunk within the body to retain its moisture. Lungs are eminently adapted for this function. In aquatic animals the ova and sperms are shed into the water, where fertilization and development take place. This is impossible in terrestrial animals. Copulatory organs are adaptations that permit fertilization within the body of the female. The hard shell and other embryonal envelopes like the amnion, and intra-uterine gestation are adaptations for life on land.

Parasitic adaptations.—A number of adaptations for parasitic mode of life have been discussed under the malarial parasites, the liverfluke and tapeworm. These include reduction or elimination of organs of locomotion, organs of special sense and alimentary canal, and extra-ordinary development of the reproductive organs and mode of reproduction.

Protective adaptations

What are protective adaptations ? Some of the adaptations protect the animal from its natural enemies. The adaptations serve as its means of defence. An animal may defend itself either by 1. counter attack or 2. by hiding. Most animals follow the principle that discretion is better than foolhardiness and avoid the enemy by concealment. A ***natural enemy*** is a predator or a parasite that is a member of the same habitat. Though an enemy of practically every animal, man is not a *natural enemy*. Protective adaptations therefore do not confer immunity from him. Moreover these adaptations are not also cent per cent effective against any particular enemy. They merely minimize the risk of death or injury from enemy action.

Natural enemies hunt their prey by 1. sight and 2. smell. The adaptations that are meant to protect the animal are thus either ***visual*** adaptations or ***non-visual*** adaptations. Visual adaptations comprise the external attitude, the appearance, colour, shape or behaviour which save the animal from a particular enemy. They include : 1. Protective colouration, 2. Mimesis or Protective resemblance, 3. Terrifying appearances, 4. Warning colours and 5. Mimicry. The non-visual adaptations include : 1. Stings, 2. irritating hairy covering, 3. irritant secretions, 4. protective shells, envelopes, etc , 5. autotomy, 6. poisons, 7. unpleasant taste or 8. foul smell.

VISUAL ADAPTATIONS

Protective colouration.—Protective colouration is harmony of colour, tone and shading of the body with the surroundings. Its effect is conceal-

FIG. [illegible]. Protective resemblance. A. The male headed grasshopper is green and inconspicuous amidst the foliage. B. *Sathrophyllia*, a peg-horned grasshopper at rest on a pomegranate twig is easily mistaken for a twig.

ment; the animal is indistinguishable from the background. The enemy fails to see its prey, which thus escapes from death.

Concealment is achieved by 1. doing away with the outline of the body, 2. doing away the shading that gives a solid appearance and 3. effacement or disguise of the shadow cast on the background. The outline of the body is disguised by spots, stripes and irregular patches of some colour that contrasts with that of the background. The effect of such ***disruptive colouration*** is that when the animal is in its natural abode, it 'melts away' among stones, pebbles or shadows of leaves. ***Counter-shading*** effaces the body perspective. The upper surface of the body is darker but the underside lighter in tone. The light from the sky illuminates the upper side more and the underside less. The result is an even tone all over and solid appearance is lost. The cast shadow is concealed by the animal pressing close against the background, by lying flat on the ground. Counter-shading, disruptive colouration and colour harmony of the animal with its background give rise to uniform tone and make it invisible to the enemy that is mostly colour blind. The natural enemies that hunt by sight always associate motion with living objects. The animal that harmonizes with the background is not seen by the enemies so long as it is perfectly motionless. Some animals actively freeze into stillness and sham death when danger threatens. Stillness therefore aids protective colouration.

Polar animals, like the polar bear, polar fox, etc. are white. Against the background of white snow they are invisible even at close quarters. The green colour of grasshoppers (Fig. 457), caterpillars, snakes and tree frogs that live amidst foliage, has a similar concealing effect. Many desert animals like the deer not only have the tawny brown colour that harmonizes with sand but also combine counter-shading and disruptive camouflage (pronounced *ka-moo-flazh*) markings. The colours and tones of eggs of numerous birds that breed in open nests or on open ground, for example, plovers (*Vanellus*), gulls and larks, match those of the ground often strewn with pebbles and stones. Some animals like the flatfish (Fig. 459), tree frog (Fig. 320) and chameleons (Fig. 322) actually change their colour to match with the surroundings. A number of insects (Fig. 458) that inhabit bark of trees not only harmonize with the colour of the bark but even have the same blotches and speckled appearance.

Mimesis.—Mimesis is ***protective resemblance***. The animal resembles some other animal, plant or other natural objects of the habitat not only in colour and marking but also in shape, size, appearance, surface structure and other details. The natural enemy therefore mistakes it for

some useless object; it fails to detect it. The effect is concealment of the animal from its enemy. Several grasshoppers (Fig. 456), *Phyllium bioculatum* the leaf-insect (Fig. 230) and *Carausius* the stick-insect (Fig. 230) have, for

FIG. 457. A marine crab with sponges and Bryozoa growing on it is inconspicuous to its enemies against a background of sponges and Bryozoa.

FIG. 458. Protective resemblance. Bark bugs common on neem trees resemble the neem bark in colour and markings and are indistinguishable from the background unless they move.

example, a surprising resemblance to leaves or sticks amidst which they live and for which they are easily mistaken. *Kallima* or the dead-leaf butterfly (Fig. 460) is a classical example. The wings of this butterfly are beautifully

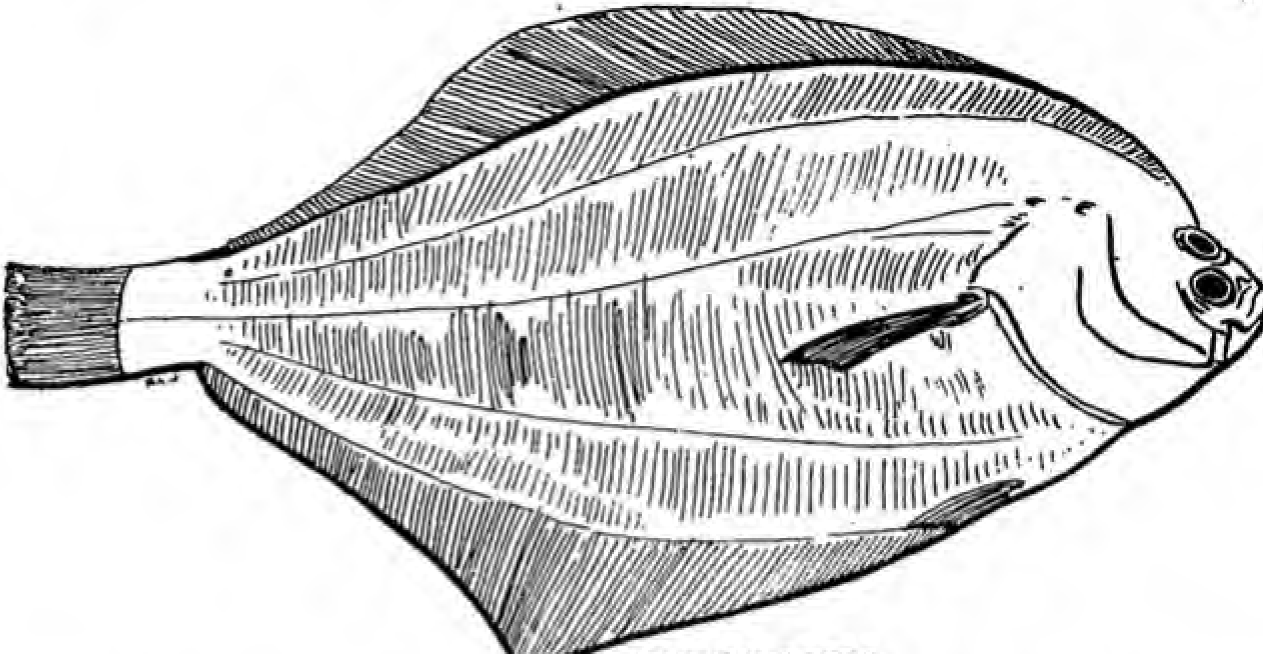
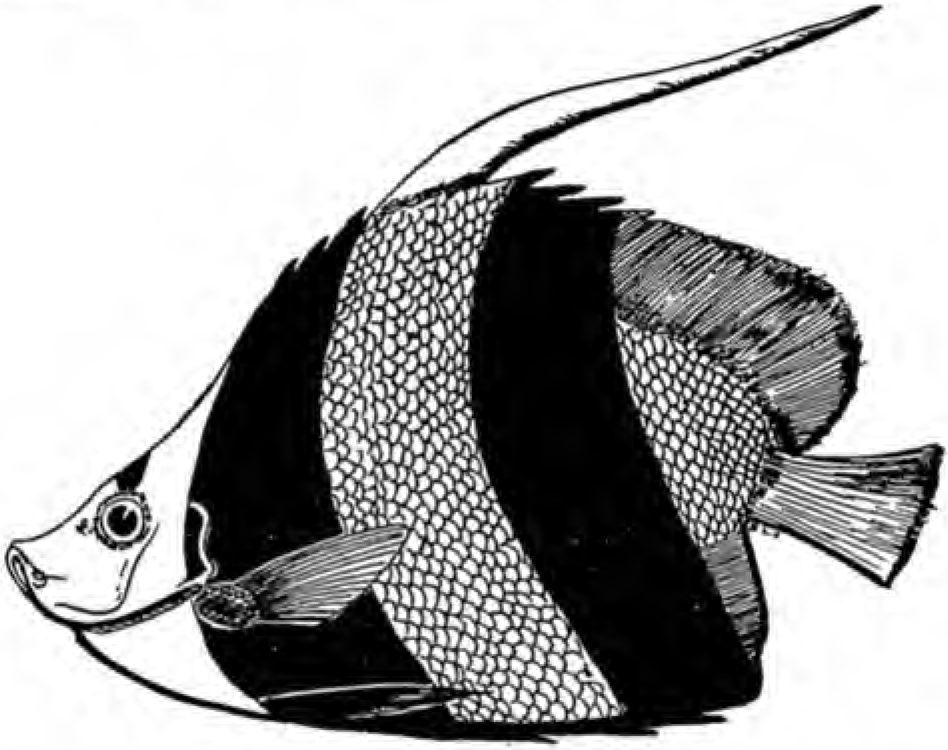


FIG. 459 *Pleuronectes* is capable of changing the colour of the upper surface to match with the background and thus becoming inconspicuous to its enemies.

FIG. 460. Protective resemblance of *Kallima*, the dead-leaf butterfly which rests with the wings folded, exposing the under surface of the wings that is coloured and marked remarkably like a dead leaf. On the left is the leaf and on the right the butterfly.

coloured above dark brown, yellow and iridescent blue, that make it one of the most conspicuous objects when flying. When the butterfly however settles down on a twig, the wings are folded with their upper surfaces together. This exposes only the under side, which is dull brown like a dead leaf and also has a line to correspond to the midrib and blotches to match those of the leaf. In shape the folded wings resemble a leaf. *Kallima* that is thus resting is perfectly indistinguishable from among the dead leaves.

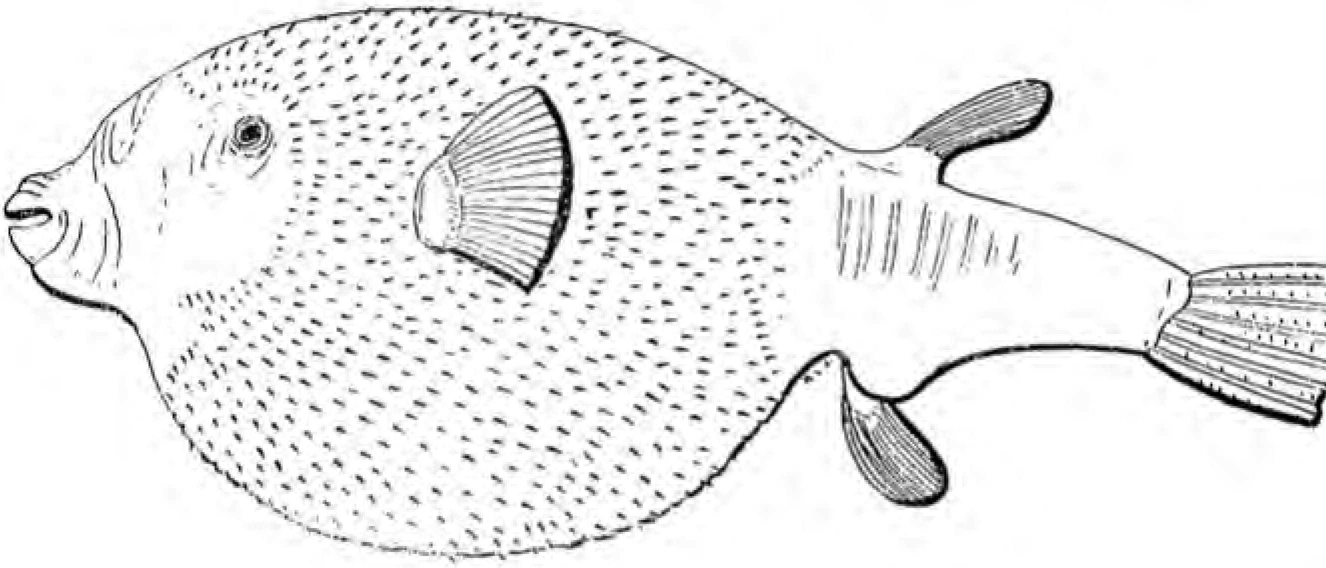


HEINOCHUS

FIG. 461. *Heinochus* is a common fish of coral reefs Its brilliant yellow and black effectively conceal it among the branched corals. It is an example of camouflage marking.

Terrifying appearance.—Terrifying appearance is cent per cent "bluff". The defenceless animal makes no attempt to hide from the enemy but actually advertises its presence. The harmless and fully edible animal takes up such an attitude or assumes such an unusual appearance that the enemy is partly confused, partly surprised and partly frightened and desists from attacking. Several green-coloured grasshoppers, when surprised by an enemy, spread their wings and suddenly expose red spots from the underwing and also produce a whirring noise. The enemy that was about to snap the grasshopper becomes confused by this sudden apparition and hesitates. The grasshopper has by this time jumped off before the enemy has recovered his balance.

Warning colours.—Warning colours comprise bright and contrasty red, yellow or black that advertise the unpleasant taste, foul smell, the toxic or irritating nature of the animal to the enemy. They warn the intending attacker of the unpleasant experience he will have if he persues the attack. The animal is thus protected not by concealment but by advertisement. This adaptation is in the nature of a sign board that says "wet paint—touch me not". Many butterflies, for example, *Danaus chrysippus* (See



GLOBE FISH

FIG. 462. The globe fish's means of defence is by producing a frightening appearance. It scares away any intending enemy by swallowing air or water till its body becomes bloated like a balloon and the spines on the skin stand erect.

Frontispiece, also pl. iii.) the caterpillars of which feed on poisonous plants, possess an acrid or unpleasant taste to birds and lizards. These butterflies are very showily coloured bright yellow, red, orange or black. They make no attempt to hide themselves but fly boldly, fully exposing their colours. The enemy that has learnt by experience to associate these bright colours with the unacceptable nature of the butterflies as food, avoids them at sight. Wasps and hornets that can inflict painful and paralyzing stings also have such warning colours.

Mimicry.—Mimicry is bluff; it is false warning colouration. An animal that is perfectly edible and defenceless has the same general appearance and warning colouration as another of the same habitat that is unacceptable to the enemy. Mimicry is thus "sailing under false colours"! It is the proverbial wolf stalking in sheep's skin! The result is the enemy mistakes the one it relishes for the other it has learnt to avoid.

The English Naturalist BATES, who explored the Brazilian forests in South America for eleven years, discovered mimicry. He found that Heliconid butterflies not accepted by birds and Pierid butterflies relished by them flew together and had the same general warning colour scheme (Fig. 463). This imitation by a harmless species of a protected one is known as ***Batesian mimicry***.

FIG. 463. Batesian mimicry between A. an edible butterfly (mimic) and B. an inedible Heliconid butterfly (model). Insectivorous birds mistake A for B, which latter they do not like; A thus shares with B the immunity from attack because of its resemblance.

Later, FRITZ MÜLLER, a German Naturalist, found that a number of species of butterflies that are not edible by birds have the same warning colouration. The chances are that an inexperienced bird catches one or two specimens of one species, finds them unsuitable and in future avoids all that look alike. The effect of this adaptation is that the mortality of any one species is proportionately less when the bird is learning to avoid them. This

kind of adaptation is called ***Müllerian mimicry*** in contradistinction to Batesian mimicry.

In addition to butterflies, mimicry is met with in a number of other animals also. Some spiders that are associated with ants, for example, not only have the same warning colours but also the general appearance (Figs. 467). They are mistaken for the ants by their enemies.

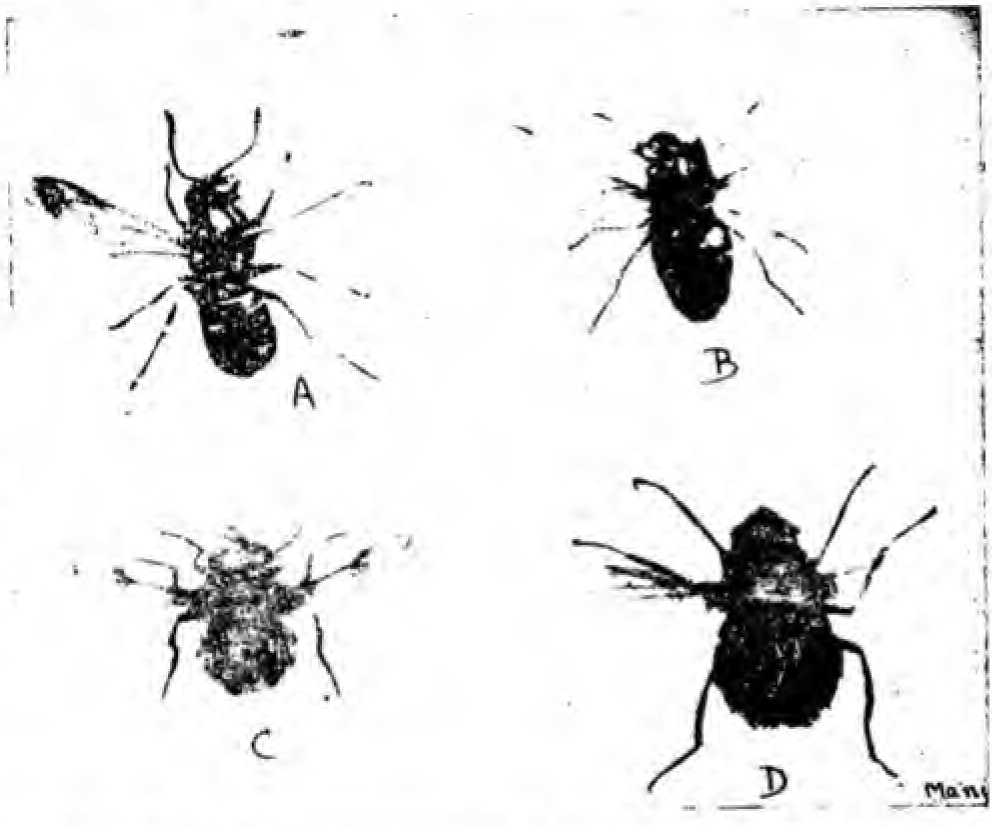


FIG. 461. Batesian mimicry between A. wasp that has sting and B. a harmless fly; and C. a bumble bee that can sting and D. a bombus fly that cannot.

NON-VISUAL ADAPTATIONS

Among the non-visual protective adaptations may be mentioned: 1. the spines on the body of the hedgehog, 2. the offensive odour of skunk, 3. the hard shells of certain Mollusca and 4. the cases of leaves, sticks, etc., in which several insects (Fig 466) live. Stings of insects, hydra, sting-ray fish and the electric organ of the torpedo fish that give an electric shock, are other examples. The horns of cattle and the hoofs of horse and donkey are also similar adaptations.

4. DISTRIBUTION OF ANIMALS

Distribution of animals includes 1. distribution in space and 2. distribution in time. *Zoogeography* deals with the present distribution of

animals in space. *Palaeozoology* concerns itself with the animals that inhabited the earth in the past.

DISTRIBUTION IN SPACE

Present distribution.—No species of animal is found all over the world. Each species is restricted to a definite ***range*** or area of distribution. Some animals have a limited range while others have extended ranges. A few are ***cosmopolitan,*** i.e. occur all over the world. The factors that

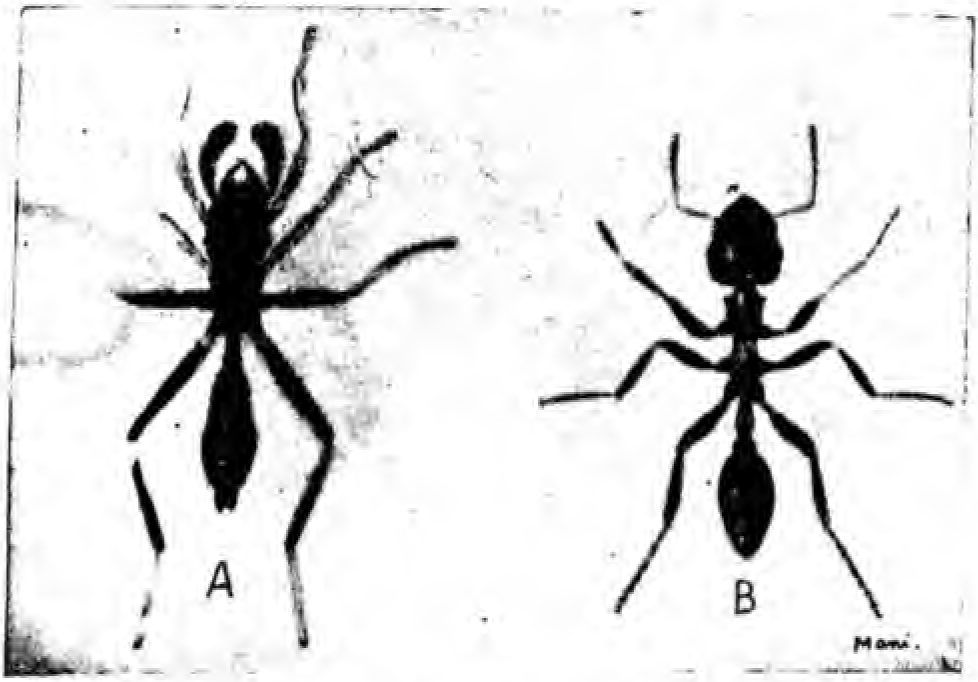


FIG. 465. Batesian mimicry between A. a poisonous spider and B. a harmless ant.

limit the distribution of an animal are called ***barriers***. Some of the important barriers include 1. physical barriers like land for an aquatic animal or water for a terrestrial animal, insurmountable mountains, deserts, etc., 2. climatic barriers like unfavourable temperature, rainfall, sunlight, etc. and 3. biological barriers such as lack of food, existence of competitors, natural enemies, diseases, etc. Although all the oceans form a single mass of water, marine animals are rarely cosmopolitan. Pelagic species cannot reach the bottom because of the great pressure and the abyssal forms cannot inhabit the surface because their body would burst under reduced pressure. Animals of the tropical seas are incapable of existing in the polar seas.

The range of a species thus surrounded by barriers to the dispersal of the animal leads to ***isolation***. Geographical isolation 1. protects the species, 2. preserves archaic characters or 3. encourages radiative adap-

tations. Australia for example has a fauna that is peculiar to it. Islands that are close to mainland do not differ in their fauna but the oceanic islands have characteristic fauna. Cape Verde Islands, 500 miles off the west coast of Africa and Galapagos at about the same distance off South America have similar physical conditions but possess different faunal types. Cape Verde

[illegible] caterpillar of *Clania*, the psychid moth, is effectively protected [illegible] the strong case of sticks and thorns it make[illegible] round its [illegible]

Island fauna resembles that of Africa and that of Galapagos is similar t[illegible] South American.

A species or a closely related species generally occurs in ranges tha[illegible] are contiguous. The distribution is then described as ***continuous***. Thi[illegible] however is not always the case. A species or genus occurs in small areas fa[illegible] apart geographically. Their distribution is ***discontinuous***.

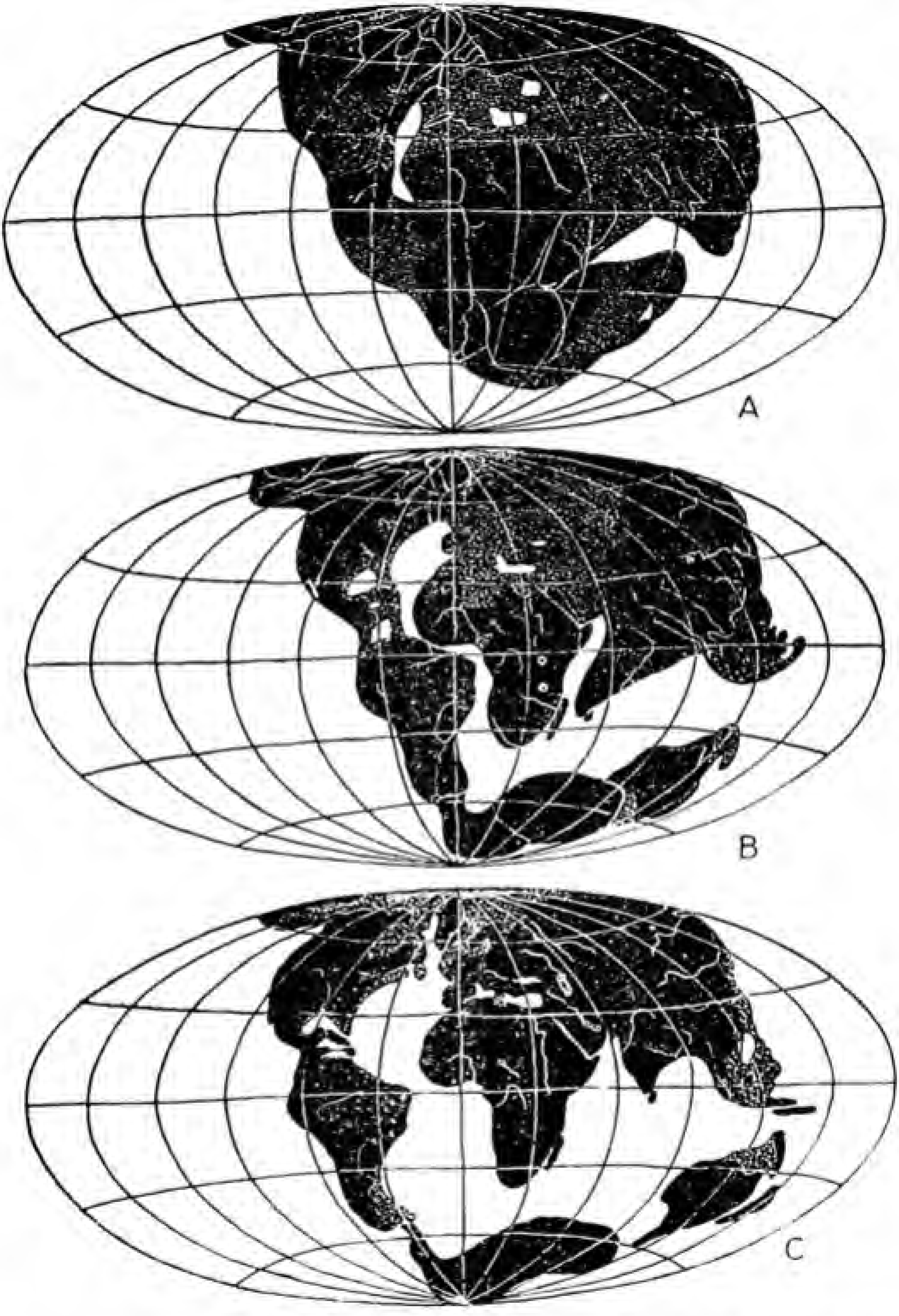


FIG. 467. Diagrammatic reconstruction of the map of the world for three geological periods: A. Upper Carboniferous, B. Eocene, and C. Pleistocene to illustrate Wegener's theory of *continental drift*, that alone explains the discontinuous distribution of animals. Land masses in black, shallow seas grey and oceans white; latitudes, longitudes and rivers arbitrary to facilitate recognition of the continental areas. (*Adapted from Wegener, Die Entstehung der Kontinente u. Ozeane.*)

Large flightless birds like emu, cassowary, ostrich, etc., comprising the Ratitae of older books, occur, for example, in Australia, Africa and South America. Tapirs occur in Malayasia and Central America. Marsupial mammals are found in Australia and South America. Dipnoi or lungfishes occur in tropical South America, Africa and Australia.

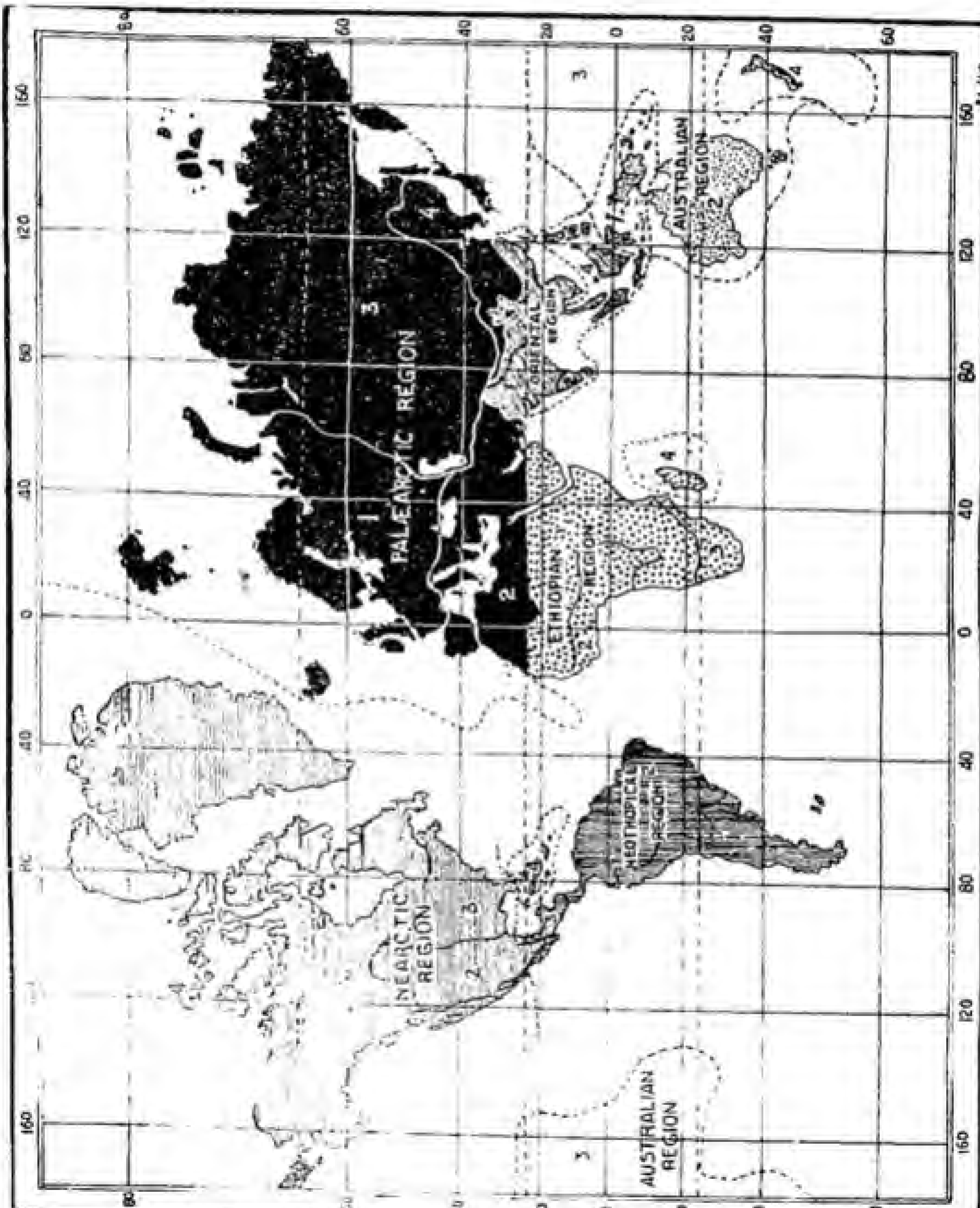


FIG. 468. The zoogeographic realms are the largest units of animal distribution and are defined by the land animals peculiar to each.

Wegener's theory of ***continental drift*** explains such discontinuous distribution. The earth contains a denser core that is subjected to tremendous pressure and high temperature. On this core lies

a thin crust of lighter rocks that compose the continents. Centrifugal force due to earth's rotation, tidal action of moon, etc., cause sliding movements of this crust on the denser core that periodically softens on the surface by reduction of pressure or for other reasons. The continents actually *drift* on the surface of the earth. At one time there was a single land mass, the ***Pungea***, which suffered two fractures (Fig. 467). The fractures gaped and the broken masses drifted apart. Australia and Antarctica broke away from South America very recently after appearance of the various animals mentioned above. The regions thus came to be isolated.

Faunal Divisions of the Earth.—(Fig. 468) On the basis of present distribution of animals, the land surface of the world is divided into six ***regions***: 1. Palaearctic, 2. Nearctic, 3. Neotropical, 4. Ethiopian, 5. Oriental and 6. Australian. The Palaearctic and Nearctic together constitute the Holarctic. The Holarctic fauna include deer, bison, wolves, beavers, etc. The Oriental fauna include Indian elephant, orangutans, gibbons, pigmy musk (*Tragulus javanicus*), numerous families and genera of birds and insects The Ethiopian Region is characterized by many families that are peculiar to it: Hippopotamus, giraffes, antilopes, zebras, chimpanzee, gorillas and ocapies. Carnivora like tiger, cat, hyena and wolf are absent but lions are abundant. The Australian Region differs sharply from other regions Its geographical isolation, combined with its separation from Antarctica and South America (Fig. 467C) comparatively recently, have preserved many archaic mammals like the Monotremata and Marsupalia. True endemic placental mammals are absent. Birds include the *Apteryx*. The Neotropical fauna is also sharply different from the rest. It includes Edentates like armadillos, sloths and ant-eaters; marsupials, platyrrhine monkeys, marmosets, vampire bats; peculiar birds like toucans, guana, rheas or the American ostriches; peculiar snakes like anacondas.

DISTRIBUTION IN TIME

Palaeozoology

Palaeozoology deals with the animals which flourished in the past and disappeared without man having ever seen them. Innumerable seems the number of animals that exist today, but this number is a very small fraction of those which lived in the past and became ***extinct***, *i.e.*, passed away without leaving behind any living representatives. Our knowledge about them is derived from their petrified bones, teeth, etc., which are found as ***fossils*** in rocks in different parts of the world.

What are fossils? The term fossil (from *fossores* to dig) was originally employed for anything dug from the earth. In palaeozoology a fossil (Fig. 469) includes all traces and remains of the animals that belonged to the geological age *other than the Recent.* When an animal dies, the

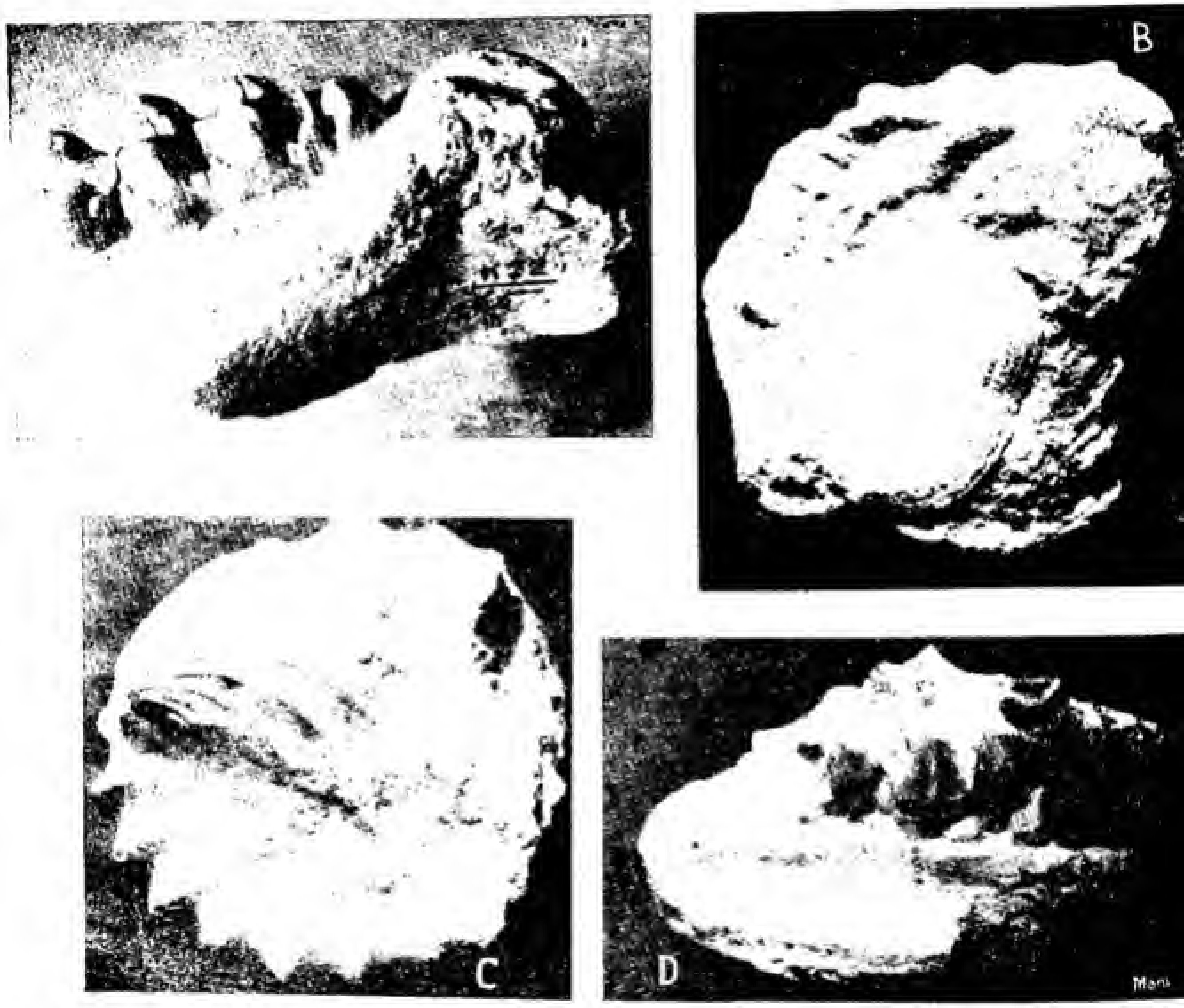


FIG. 469. Types of Tertiary fossils from India. A. Petrified mandibular ramus with teeth of [illegible], an extinct pig. B. A block of Multani mutti with a semi-mineralized molluscan shell. C. Petrified remains of the shell of a Brachiopod and Ammonite. D. Petrified upper jaw and teeth of *Aceratherium* an extinct hornless rhinoceros that roamed in India about 20 million years ago.

soft parts like skin, flesh, etc, rapidly decay or are devoured by carrion feeders. The hard parts like bones, teeth, nails, scutes and scales may be scattered and washed away by rain or torrents and reach the sea or a lake. They may finally settle down and be covered by layer after layer of muddy sediment. An aquatic animal undergoes similar decay

Fig. 170. A piece of shale with cast of an extinct Trilobite from the Palaeozoic strata of India.

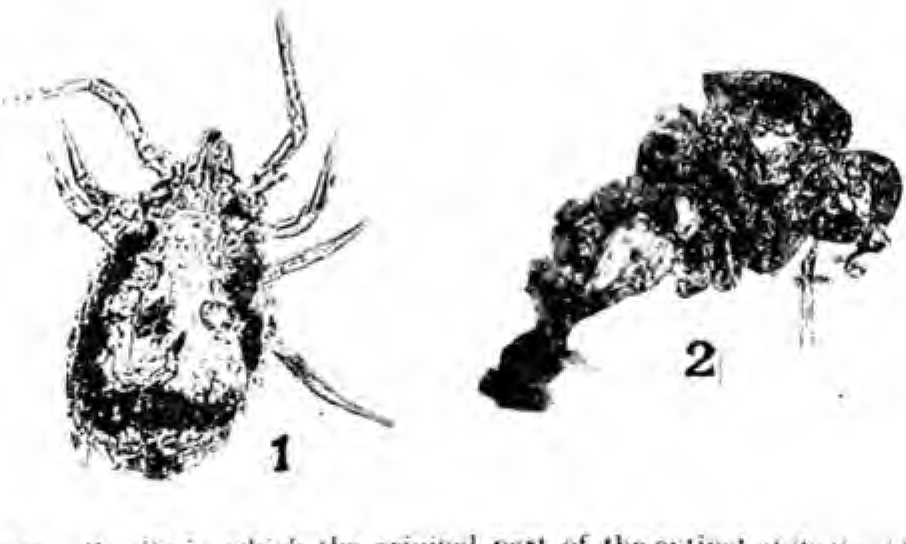


Fig. 171. Fossils in which the original part of the extinct animal is preserved. 1. An extinct mite, *Gamasus fossilis*, and 2. an extinct gnat, *Chironomus* [illegible] of the Eocene Epoch, embalmed in salt in the Saline Series of the Salt Range, the Punjab (now Pakistan). (*Original photomicrographs of slides made by the late Prof. Birbal Sahni, reproduced by the courtesy of the Entomological Society of India*).

of soft parts but the hard parts sink and become buried. The fragments which thus get buried become preserved as fossil. Most fossils thus form in sediments under water. The sediments accumulate layer by layer and in course of time by pressure become compacted into the ***sedimentary rock.*** Animal remains that get covered by mud from mud volcanoes, or ash and lava from active volcanoes may also be fossilized. It is mostly fragments that are thus fossilized and it is only extremely rarely that complete skeletons become buried.

FIG. 475. A piece of argillaceous shale from the Inter-Trappean Tertiary of Nagpur, with the cast of the elytra (wing cover) of an extinct beetle, ***Palaeotanymecides hislopi***. The fragment of the elytra had lain on the soft mud before it had become compacted into rock and thus left on it a faithful impression of all details of surface structure. The elytra itself decayed in time and the cast hardened into the fossil. Enlarged. *(Original photograph of a specimen loaned for study by the late Prof.* ***Birbal Sahni****, reproduced by the courtesy of the Entomological Society of India).*

In several cases the fossil consists of only the foot prints or casts of some part of the body of the extinct animal in soft mud of an ancient lake or sea, which dried up before becoming buried under further sedimantation and finally compacted and hardened into rock. In very rare cases the

entire carcases, as for example, the woolly mammoth, have been 'frigidaired' in the frozen mud cliffs of Siberia. Some fossils, like those of the extinct woolly rhinoceros, consist of the whole body pickled in mineral oil pits. Small insects and (Fig. 471) plant fragments have been embalmed in brine that dried into rock salt as in the Salt Range of the Punjab. Sometimes small insects, spiders, etc., became entangled in gums and resins oozing from ancient trees. The resins dried, hardened and became buried with the enclosed animals. These fossil resins constitute *amber* and *copal*, in which the organisms are preserved much in the same way as mounted in canada balsam on a glass slide in the laboratory. It is thus only the geological age and not its composition that determines whether a specimen is a fossil.

Changes during fossilization.—Animal remains that get buried in sediment undergo various changes during fossilization. Some of these changes are chemical and others are mechanical. The chemical changes include 1. decomposition, 2. mineralization or petrifaction, 3. carbonization, 4. infiltration, etc. Mechanical changes include crushing, distortion, faulting, folding, etc. During mineralization, foreign substances like carbonates of calcium, silicon, iron pyrites, iron oxides, etc., dissolved in water, replace the organic material of the buried bone molecule by molecule. The remains of the dead animal thus become ***petrified*** or turned into stone. Carbonization occurs under water; coal is the fossil remain of ancient forests. The muddy ooze flows into the hollow parts, such as inside shells, and takes on the mold or imprint before the shell decays (Fig. 469). Chance alone governs the formation, preservation and discovery of fossils. Not all animals that flourish become fossilized. Animals like worms that have no hard parts have thus practically no chance of becoming fossilized. Even among others it is only one or two out of the millions that die ever become buried. Fossils are also not free from decay and destruction. The rock that encloses fossils undergoes weathering and the fossils gradually disintegrate.

Geological succession and chronology.—Sedimentation of fine mud, sand or other similar material takes place layer by layer, one above the other in ***strata***. The strata at the bottom are thus laid first and those at the top are laid last. Such a sedimentation is a gradual process that requires millions of years. During this long interval various types of animals flourish and perish. Lower strata enclose fossils of early animal types and the top of late types. The early fossils consist only simple types like Protozoa and Coelenterata. Above them appear the fossil Arthropods. Still above lie the primitive Chordate forms, the reptiles and finally on

top of all come the fossils of birds and mammals. There is thus a regular ***succession*** of fossils from simple to complex types.

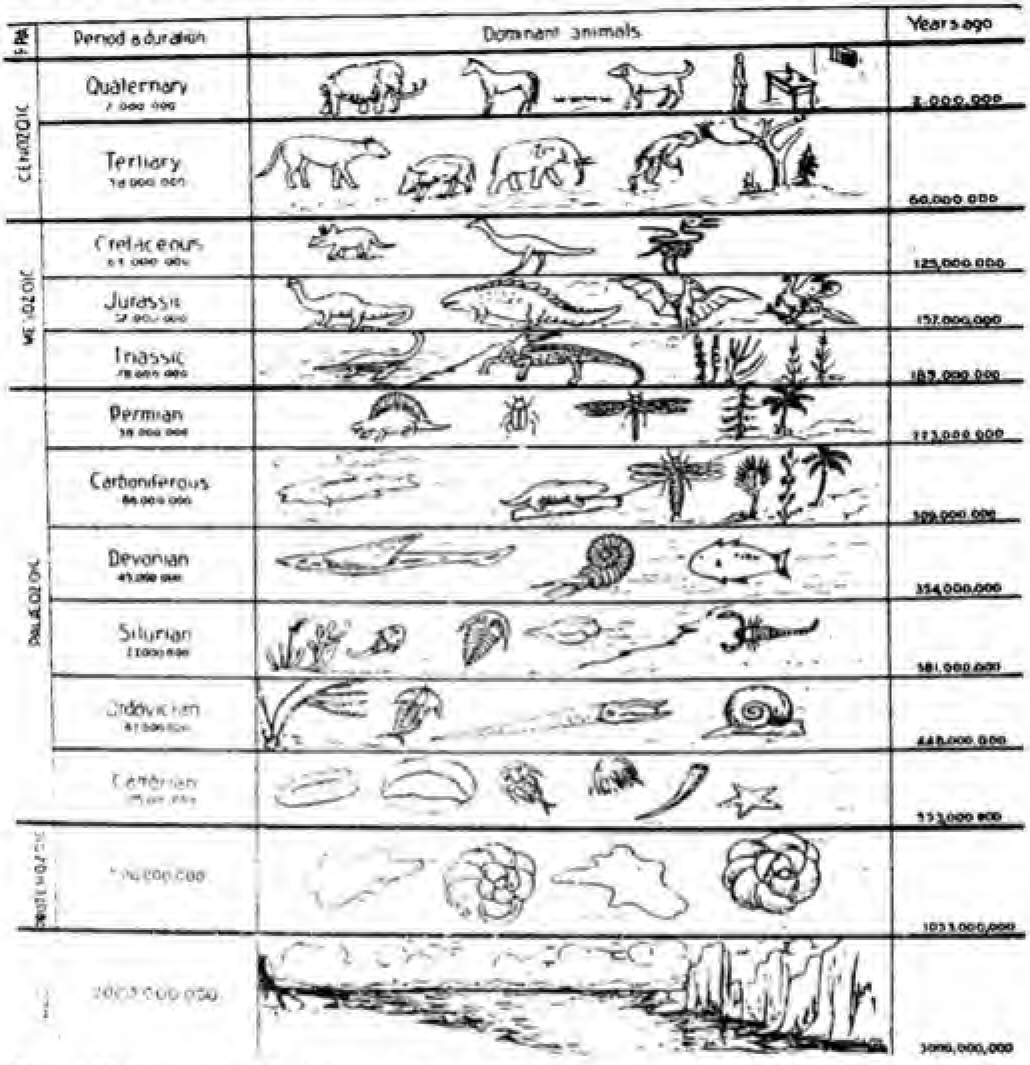


FIG. 473 — Geological chronology, with examples of the dominant animals. The Earth was born nearly 3350 million years ago. The unimaginably enormous stretch of time that has since passed is divided by geologists into the Eras Azoic, Proterozoic, Palaeozoic, Mesozoic and Cenozoic. The Eras are subdivided into Periods, Periods into Epochs and so on. Each geological period of time was characterized by its own special types of animals, that appear, reach their peak and disappear in succession. The Azoic was a period of 'No Life', the Proterozoic one of unicellular life, Palaeozoic of primitive metazoa — all life was in sea. The first land animal — a scorpion — came in the Silurian. The Mesozoic was an age of reptiles and the Cenozoic is probably one of mammals and insects.

The earth was born out of the Sun about 3500 million years ago.* Sedimentation and formation of the stratified rocks however commenced only after the earth had solidified and cooled sufficiently to permit the

* Recent refined methods of estimating, using the so-called "radium clock", place the age of the earth at 3,350 million years. Surprisingly enough, according to the ancient Hindu scriptures, the earth is now (in 1950 A. D.) 1,972,949,051 years old, a figure close to 2000 million years widely accepted by many modern scientists for the expanding universe.

condensation of water. At this remote period there was no life on the earth. Fossils appear only after a long interval. ***Geological chronology*** or time scale begins with the formation of the first sediments. The total thickness of the sedimentary rocks exceeds 30,000 metres. The formation of such an enormous deposit must have taken a vast stretch of time that can only be measured in millions of years. This period is divided into the Azoic, Palaeozoic, Mesozoic and Cenozoic Eras. The Eras are further divided into Periods (Fig. 473) and the latter into Epochs. The Palaeozoic Era comprises the Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian Periods. The Mesozoic Era includes the Triassic, Jurassic and Cretaceous Periods. The Cenozoic Era is divided into Tertiary and Quaternary Periods. The Tertiary Period is subdivided into the following Epochs: Eocene, Oligocene, Miocene and Pliocene. The Quaternary comprises the Epochs Pleistocene and Recent.

Each of these Eras, Periods and Epochs possesses its characteristic fossil types. The Cambrian fossils are wholly of marine animals such as Trilobites (Fig. 470), Ostracoderms, Mollusca, Annelida, Echinodermata, Brachiopoda, Sponges and Radiolaria. The first fishes and the land animal scorpion appeared in the Silurian. The Devonian fossils include Myriopods and Amphibia. The Carboniferous Period saw a mild and humid climate in the northern hemisphere. Land plants like the vascular Cryptogams, Gymnosperms, etc. flourished in great abundance. The first reptiles and insects came into being. The Permian period was one of mighty climatic change and it was a period of vast glaciation. Reptiles and insects dominated. The Trilobites had become extinct.

During the Mesozoic Era the reptiles gained ascendency: Dinosaurs appeared at the beginning in the Triassic Period and became extinct at the end of the Cretaceous. The first flowering plants, birds and primitive mammals also appeared towards the close of this Era.

The Cenozoic Era saw the rising of modern bees, butterflies, birds, monkeys, apes, elephant and horse. The Pleistocene was marked by the birth of man.

The Geological age of any fossiliferous rock is determined by various methods, like stratigraphy and superposition, chemical and other structure of the rock, comparison of types of fossils, magnetic orientation of crystals in the rock, lead isotopes estimation and radio-active substances, etc. The Palæozoic Era began about 553 million years ago and ended 185 million years ago. The Mesozoic Era ended 60 million years ago The Pleistocene Epoch was two million years ago.

Extinction of animals. – Many fossil genera, like Foraminifera, remain unchanged through a number of Epochs. These constitute the ***persistant*** types. Others, the ***variable*** types, change rapidly, develop into a great variety of forms in successive periods and die out completely, as for example, the Trilobites, Dinosaurs, etc. They become ***extinct***. The causes of extinction of animals are not still clearly understood. In some cases changes in external conditions, like the distribution of land, water, lack of food, encroachment of natural enemies must have led to extinction Some must have perished through rivalry and civil warfare. Others met their doom by over-development in some direction, for example, size as in the Dinosaurs. In many cases the race appears to die off without external help through sheer superannuation. As in individuals so in the race the reproductive functions gradually decline and the animal becomes extinct in due course.

RESUME

I. Animal Ecology.

1. The fundamental principle of animal ecology states that every animal forms an integrated part of the environment. The animal and its environment are mutually interactive and adjustable. The result of this interaction is a dynamic equilibrium that has within itself the power of re-establishment if the balance is disturbed.

2. The environmental influences that interact with the animal constitute ecological factors. These factors are of three kinds : abiotic, biotic and superorganic.

3. Each factor has a minimum, an optimum and a maximum value.

4. Temperature is one of the most important of the abiotic factors. Increase of temperature has a stimulating effect on animals upto the optimum point, beyond which it is not favourable. The fatal temperature for most animals is 60°.

5. Other abiotic factors include humidity, pressure, wind, light, etc.

6. The biotic factors comprise intraspecific and interspecific relations of animals and relation between plants and animals Intraspecific relations include : concurrence, cannibalism, herding, association of the sexes, parental care and social life. Interspecific relations include epizoism, commensalism, mutualism, symbiosis, slavery, predatism, parasitism, mimicry and myrmecophily. Plants and animals are mutually interdependent in the food chain. Some plants are enemies of animals. Some animals are enemies of plants. The relation between pollinators and plants is a case of mutualism between plant and animal Symbiosis between plants and animals also exists.

II. Animals in their haunts

7. Animal haunts comprise salt-waters, fresh-waters and land.

8. Marine animals are classified into the plankton, nekton, littoral, neritic and abyssal.

9. Fresh-water haunts include lakes, rivers, swamps, marshes, etc.

10. Terrestrial habitats include the tundras, forests, grasslands and deserts.

III. Adaptation.

11. Adaptation is capacity to respond and adjust to environment in such a way that it ensures preservation of the animal.

12. Adaptative convergence occurs in unrelated animals of the same habitat. Adaptative radiation occurs in the same class of animal that occupies different habitats or has different modes of life.

13. Some of the important adaptations for special modes of life involve adaptations for aquatic life, amphibious life, terrestrial life, flight and parasitic life.

14. Many of the adaptations protect the animals from their natural enemies. These fall under two groups : visual and non-visual.

15. Visual adaptations protect the animal either by concealing it or by warning its unacceptability to the enemy. They involve : protective colouration, protective resemblance, terrifying appearance, warning colours and mimicry. The first two are cryptic but the others advertise the presence of the animal.

IV. Distribution of animals.

16. Zoogeography deals with distribution in space and palaeozoology with distribution in time.

17. Each species occurs in a definite range that is surrounded by barriers to dispersal.

18. Distribution is either continuous or discontinuous. Discontinuity of distribution is explained on the basis of the theory of continental drift.

19. Our knowledge of the animals of the past is derived from fossils A fossil is trace or remain of animals that flourished before the beginning of the present geological epoch. Fossils comprise petrified hard parts, carbonized remains, imprints, casts, frozen or embalmed remains.

20. The succession of fossils forms the basis of geological chronology. The early fossils belong to wholly simple marine forms. These are succeeded by complex types, then by first terrestrial forms and these in turn by more and more complex forms.

21. Among the causes that led to extinction of animals superannuation and race senescence are important.

CHAPTER XXVI

GENERAL PRINCIPLES OF BIOLOGY (*Continued*)

1. VARIATION.

What is variation ? No two individuals of a species of animal are exactly alike. There are always minute differences. These differences constitute variation. Variations include not only morphological characters like size and colour, but also physiology, behaviour, etc. Some of these differences arise from the inherent property of living matter to vary and others are due to the effects of environment Variations are either ***continuous*** or ***discontinuous***. Continuous variations comprise small graded deviations from the typical condition of the species, the extremes being connected by intermediate stages that pass insensibly into one another. The height of man for example fluctuates in this way : there are people who are 6 ft. tall, others only 5 ft. tall and many who are in between, *e.g.*, 5'-6", 5'-7" and so on.

Discontinuous variations or mutations comprise sudden or abrupt deviations from the normal condition, not connected by a graded series of intermediate forms. Mutations are generally very rare. HUGO DE VRIES (pronounced *Hoogo de frees*), a Dutch botanist, first drew attention to the importance of mutations in 1886. He described several mutations in *Oenathera lamarckiana*, the evening primrose plant. Sometimes hornless cattle arises in a herd of horned ones and gives rise to hornless progeny. There are no intermediate forms of cattle such as some with small horns, others still smaller, still others with vestigial horns and so on, to form a graded series between the horned and the hornless. The hornless form appears all of a sudden. In recent years MORGAN, an American biologist, has described nearly five hundred mutations in *Drosophila melanogaster* the common bananafly (vinegar fly). Each of these ***mutants*** arises suddenly and independently and continue true generation after generation. Mutations in *Drosophila* include changes of size, colour, head, eyes, wings, etc.

Some of the variations arise within the life-time of a single individual due to the direct effect of environment on the body. They are termed ***somatogenic*** variations or ***acquired characters***. A blacksmith, for example, has the muscles of the right hand and generally of the right side of the chest better developed than those of the left due to his habit of constant hammering with the right hand. His children are however born with

muscles of both sides equally well developed. The action of X-rays on *Drosophila* produces, for example, variations that re-appear as mutations in successive generations. These variations are called ***blastogenic.***

Some of the variations are in the nature of adaptations and others are not.

BIOMETRY concerns itself with the measurement of variation. QUETELET, a Belgian astronomer, meteorologist and anthropologist, may be said to have founded the science. The statistical study of variation initiated by him was carried further by FRANCIS GALTON, especially in genetics. In recent years the mathematical treatment of biometric problems has been greatly perfected by PEARSON in Galton's National Eugenics Laboratory, London.

Variations which fluctuate about a mean are represented by the well known *frequency of error curve.* The shape of the frequency curve gives us an idea of the range, average amount and distribution of variability. A wide-spread curve indicates a highly variable species. A measure of variability is obtained by determining the deviation of individuals from the mean for the species. The *average deviation* is then found by multiplying the deviation of each class by the number of individuals in each class, adding the products and then dividing by the total number of individuals.

Thus $$\text{A. D.} = \Sigma . f . D/n$$

Where A. D. is average deviation, Σ the mean, D deviation of each class, f the frequency or the number of individuals of the class of deviation and n the total number of individuals.

The measure of variability commonly used is *standard deviation.* This is obtained by squaring the deviation, the squares are then added and divided by the total number and finally the square root of the quotient is extracted :

$$\text{S. D.} = \sqrt{\frac{\Sigma f D^2}{n}}$$

Coefficient of variability enables us to compare variation of one with another. It is obtained by multiplying the standard deviation by 100 and dividing it by the mean.

$$\text{C. V.} = \frac{r . 100}{M}$$

Coefficient of correlation is a measure of the extent to which one character varies in agreement with another, for example, height and weight.

It is always expressed as some fraction of 1 and it may range from 0 to 1 or −1. It is obtained as follows :

$$r = \frac{\Sigma . Dx . Dy . f}{n . rx . ry}$$

Where r is coefficient of correlation,

Dx Dy, are deviations of each observed group of individuals from their respective means of height and weight for example. Σ the sum of the products, n the total number of individuals observed,

rx, ry the standard deviations for height and weight.

The uses of coefficient of correlation include :

1. to find out what parts or processes of an animal vary in unison with each other and if so to what extent they so vary.

2. to find out the strength of heredity. It affords a means of comparing the strength of a given character in successive generations and thus of measuring heredity, as for example, the amount of white colour in the coat of rats.

The expressions for mean, standard deviation and other measures of variation have varying degrees of reliability, according to the number of cases upon which we make the measurements. The larger the number of individuals measured,

the more reliable the result. The term *probable error* is used to indicate the extent to which our results are likely to be wrong. It is a value so chosen that a given instance is apt to fall within as without that value. If for example one thousand men were to measure the height of a given person, most of their measurements will doubtless differ slightly from each other. These differences will fall into a regular curve, symmetrically distributed about the true value. (*Frequency of error curve*). Statisticians divide what is called "normal" curve by lines (quartiles) into equal areas on each side of the mean. The distances of the quartiles represent the probable error. This is a definite fraction 0·6745. The probable error of the difference of two quantities is 0·6745 times the square root of the sum of the squares of the sigmas of these quantities.

2. HEREDITY - INHERITANCE IN ANIMALS.

What is heredity? Though animals show variation, each animal reproduces its own kind. Like begets like. The young of cats are always kittens, never puppies; those of dogs are always puppies, never kittens. This resemblance, based on descent, is ***heredity***. It is the passage of characters from one generation to another. Heredity is thus occurrence in animals of qualities, either expressed or latent, derived from their ancestors.

FIG. 474. Gregor Johann Mendel (1822-1884), an Austrian monk, the greatest biologist of all times. He discovered the laws of inheritance. (*Original photograph of a portrait in the Zoology Museum, St. John's College, Agra*).

These qualities include physical, physiological or psychological characters. ***Genetics*** is the subject that deals with heredity, its source and factors that govern it. Genetics is of great practical importance in raising improved breeds of animals and plants that are disease resistant, yield more milk, wool or crops and so on. ***Eugenics*** is application of the laws of genetics to human welfare.

Mendel and his work.—The fundamental laws that govern inheritance in plants and animals were first discovered by GREGOR JOHANN MENDEL (*J* in Johann pronounced as Y) (1822–1884) (Fig. 474). He was the son of an

Austrian peasant, who belonged to a family of gardeners. After his schooling, MENDEL joined the Augustinian monastery at Brunn, a centre of religious and secular learning. He was first ordained a priest but his delicate health made him unfit for this work. After a year he was appointed teacher of mathematics and biology in the monastery school. He became interested in inheritance and carried out breeding experiments with pea plants for eight years in the small garden attached to the monastery. The results of these experiments led him to formulate the laws of inheritance, now known as ***Mendelism***. He published his results in 1865-6 but nobody took any notice of his paper and the tremendous importance of his discoveries was not realized until long after Mendel's death. Mendelism was rediscovered by HUGO DE VRIES, CORRENS, TSCHERMARK and BATESON.

Mendelism.—Mendelism involves several laws that are of universal application both in the animal and plant kingdoms. These are: 1. law of paired units, 2. law of dominance, 3. law of independent assortment and 4. law of segregation. These laws may be illustrated as follows: when a true-breeding black rat and a white rat (Fig. 475) are mated, all the hybrid individuals of the first ***filial*** generation are black. When mated among themselves, these black hybrids produce in second filial generation a progeny in which some are black and some are white. On an average, the black rats are three-fourths and the white one-fourth of the progeny. The white colour that disappeared in the first generation now reappears unchanged in the second generation. If the F_2 *white* animals are again mated among themselves, the progeny is all white. One-third of the F_2 black animals, on self-mating, produces always black rats and two-thirds produce blacks and whites in the same ratio 3 : 1. The white always breeds true: gives rise to white rats. One of the three blacks again breeds true, the remaining two give rise to blacks and white once more in the ratio 3 : 1. The two contrasting characters, like black and white coat colours, are represented by a pair of factors or ***genes*** within the chromosomes of the cells. These paired genes that give rise to contrasting characters constitute an ***allelomorph***. When two such contrasting characters are brought together into a cross, one is ***dominant*** and is evident in the first filial generation. The other has not disappeared but has only receded from view; it is ***recessive***. The first filial generation contains the factors for both and is thus ***heterozygous***. In the succeeding generation, the dominant and recessive characters ***segregate*** in the ratio 3 : 1 and the recessive character thus becomes expressed. The single white rat contains the genes that produce only whites; it is ***homozygous***. One of the three blacks breeds

true and is again homozygous for the dominant character. The remaining two are heterozygous and contain the genes for both. Representing the genes for the dominant character, viz. black colour by **B** and the recessive white by **b**, the genetic formula for the parents is **BB** and **bb**. Each chromosome is diploid in the parent and haploid in gametes (vide chapter V gametogenesis). The gametes are thus **B, B** and **b, b**. On fertilization, all offsprings are

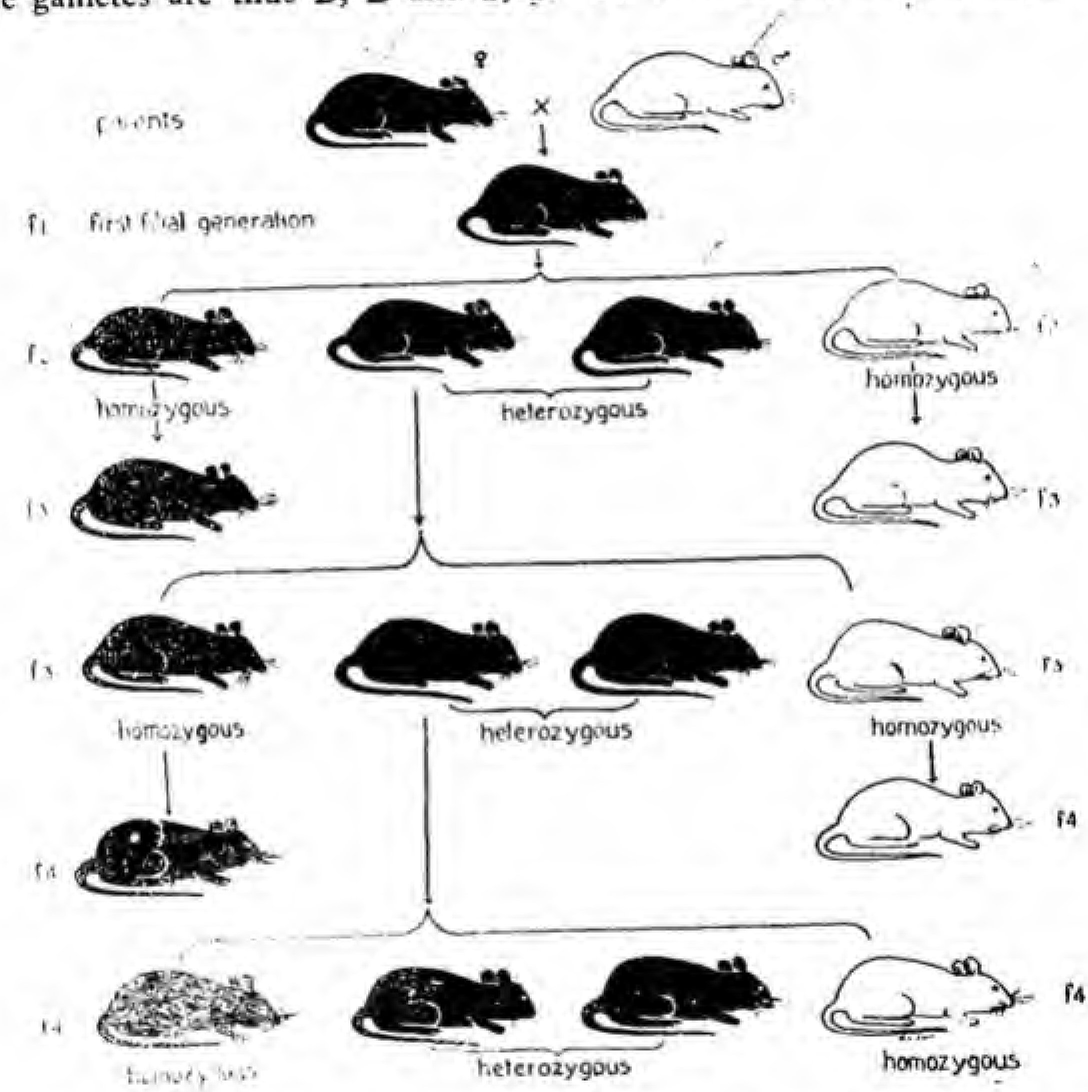


Fig. 475. Monohybrid cross with mice breeding pure for black and white colours of hair.

represented by **Bb**. In the F_2 generation the combinations possible are **BB, Bb, Bb** and **bb** thus three blacks and one white. **BB** is homozygous for dominant and **bb** for recessive character. The two **Bb** are hetrozygous. The entire genetic composition of the animal, dominant and recessive, is the ***genotype***. The expressed or the evident combination is the ***phenotype***.

When two pairs of characters enter into a cross a ***dihybrid*** results. This is illustrated in rats with black (**B**) coat dominant over white (**b**) and rough (**R**) coat over smooth (**r**). Four kinds of gametes form for each sex and sixteen matings are possible.

	Parents	*Gametes*	
P_1	**BBRR** (Black, rough)	**BR**	**BR**
P_2	**bbrr** (White, smooth)	**br**	**br**
	First filial generation :		
		Gametes	
	Phenotype Black rough **BbRr**	**BR**	**Br**
		bR	**br**

Possible matings in the second filial generation are given below :

MALE GAMETES

FEMALE GAMETES	BR	Br	bR	br
BR	**BBRR** Black, rough	**BBRr** Black, rough	**BbRR** Black, rough	**BbRr** Black, rough
Br	**BBRr** Black, rough	**BBrr** Black, smooth	**BrbR** Black, rough	**Bbrr** Black, smooth
bR	**BbRR** Black, rough	**BbRr** Black, rough	**bbRR** White, rough	**bbRr** White, rough
br	**BbRr** Black, rough	**Bbrr** Black, smooth	**bbRr** White, rough	**bbrr** White, smooth

The F_2 phenotypes thus contain 9 black rough (those with **BR** genes) and 1 smooth white. Two new combinations include 3 black smooth (**Br**) and 3 white rough (**bR**). The ratio thus becomes 9 : 3 : 3 : 1. There are $9+3=12$ blacks and $3+1=4$ whites ; $9+3=12$ rough and $3+1=4$ smooths. Each character has thus segregated in the ratio of 3 dominant to 1 recessive. This shows that the inheritance of each pair of genes is independent of the other.

In the same way in a ***trihybrid*** where three pairs of characters enter into a cross, each character is assorted independently of the others, giving rise to 64 combinations for F_2. Crossing for example short, black, smooth-haired rats with long white and rough ones results in :

Short black rough 27
Short black smooth 9
Short white rough 9
Short white smooth 3
Long black rough 9
Long black smooth 3
Long white rough 3
Long white smooth 1

Summarizing, the laws may be restated thus :

1. ***Law of paired units.***—In every cell in the body there is a pair of hereditary units called genes responsible for each character.

2. ***Law of dominance.***—When two genes of a pair are unlike. we have a heterozygous pair and only one of them is evident in the first filial generation. It represents the dominant character. The other gene which remains unexpressed represents the recessive character. The progeny of the first generation all resemble one of the parents but not both.

3. ***Law of independent assortment of the genes.***—When several pairs of genes enter a cross, each is assorted independently of the rest. When races differ from each in several pairs of factors, the inheritance of one pair is independent of the others. In other words one gene from each is included in each egg and sperm.

4. ***Law of segregation of genes.***—In breeding heterozygous animals for a pair of genes, three kinds of offspring result by chance combinations of the genes. One-fourth is a combination of the two dominant genes resulting in dominant homozygotes that breed pure for this character. Another one fourth is a combination of the two recessive genes, giving rise to recessive homozygotes that breed true for this character. The remaining half is a combination of the dominant and one recessive gene, resulting in a heterozygote, that looks like the dominant in appearance but breeds to produce one homozygote dominant, one homozygote recessive and two heterozygote dominants as before. In the second filial generation three-fourths of the progeny resemble the dominant parent and one-fourth the recessive parent.

The genes are real material particles, probably of the nature of protein bodies that possess a high degree of specificity. They also have the power of reproducing themselves. They are not scattered in disorderly fashion in the cell, but are joined together in paired strings. Each string of gene together with a certain amount of "inert" chromatin, constitutes a chromosome. Each somatic cell has a complete set. One gene of the pair is derived from the mother and the other from the father at least in biparental animals. The germ cells or the gametes contain only one member of the pair. This is due, as explained in an earlier chapter, to meiosis, during which the chromosomes conjugate, duplicate once, separate and pass at *random*

to opposite poles of the cell in two cell divisions. The total number of chromosomes and of the genes is restored when the gametes fuse at fertilization.

The combinations of genes and the Mendelian segregation are governed by the well known statistical laws of chance. This may be illustrated by a simple experiment. A blindfolded person picks up *two* marbles at random at a time from a heap of 300 black and 300 white marbles. He will naturally pick up *two black*, *two white* or *one black and one white*. He is made to put each of his pickings into a separate box, according as it is two black, two white or one white and one black. At the end we will have in one box 150 black marbles, in another 150 white ones and in the third 300 black and white. The ratio of black : black-and-white : white is thus 1:2:1. The result will be the same no matter how many times the experiment is repeated. As the genes are in equal numbers of pairs, the chance combinations are here also 1 : 2 : 1, the famous Mendelian ratio.

From the brief account of the mechanism of heredity outlined above, it must not be concluded that each gene is the inherited basis of a particular character. The same genetic factor does not always have the same effect. Changes in temperature, humidity, food and other environmental factors all influence the character. A variation is thus due to two causes; 1. to gene changes 2. environmental changes. The Amphipod Crustacean *Gammarus chevreuxi* has normally black facets in the compound eye. At a temperature of 19° C the facets from normal black-eyed form are red. Thus genetic factors interact with the environmental factors to produce characters for which they are responsible. The same character can be produced by changing the gene or by outer environment.

Sex inheritance.—Sex in many animals is an inherited condition. The genes of the sex are located in special chromosomes. Each chromosome carries an orderly arrangement of definite kinds and numbers of genes. A pair of chromosomes is connected with determination of sex in many animals. These chromosomes are called ***sex chromosomes***. The male has two sex chromosomes of a pair differing in appearance and called X-chromosome and Y-chromosome. The female possesses two X-chromosomes. During reduction division in gametogenesis the sex chromosomes go either to one cell or to the other. In the male, one half the number of sperms receives the X-chromosome and the other half the Y-chromosome. In the females all the ova receive X-chromosomes. If a sperm containing an X-chromosome unites with the ovum that possesses only the X-chromosome, the zygote gets two X-chromosomes. The offspring is thus a female. If however a sperm that has the Y-chromosome unites with the ovum, the zygote becomes XY and a male results.

Parent	Female (Homozygous)	Male (Heterozygous)
Diploid nucleus	XX-chromosome	XY-chromosome
Gametes	X X (ova)	X Y (Sperms)
Fertilization Zygote	XX XX (Females)	XY XY (Males)

The female is thus a homozygote and the male a heterozygote. This for example is the case with several Vertebrates, Insects and some Nematodes. In other animals like birds, moths, etc., the mechanism is converse of this : the male is homozygous and the female heterozygous.

Parent	Female (Heterozygous)	Male (Homozygous)
Diploid nucleus	WZ-Chromosome	ZZ-Chromosome
Gametes	W Z (Ova)	Z Z (Sperms)
Fertilization Zygote	WZ WZ (Females)	ZZ ZZ (Males)

The results of ***castration*** (destruction of the testes) confirm the view that sex is Mendelian inheritance in many animals. In Vertebrates, for example, castration of the young male may prevent the expression of masculine features but not the feminine. This would mean that the male is homozygous.

The exact mechanism of the determination of sex in several other animals is still only imperfectly understood. According to some, environmental factors affect the sex of the offspring. YOUNG showed, for example, that tadpoles of frog linger for some time in a hermaphroditic state. If these tadpoles are fed exclusively on a diet of beef, fish or frog meat, they develop into predominently female frogs. Some aphids reproduce parthenogenetically and give rise to females only throughout summer and spring but both males and females during autumn. According to others, environmental factors have no influence on the sex of the offspring.

Linkage. Many characters are inherited together. As the number of genes far exceeds the number of chromosomes, a single chromosome carries several genes. These genes pass together from parent to offspring. The characters that are determined by such genes are thus inherited together. They are said to be ***linked***. The tendency of the genes to maintain their relative position in the chromosomes in the hereditary transmission constitutes ***linkage***. If a character is linked with one sex or the other it is a ***sex-linked*** character. The colour of eye of *Drosophila* is thus a sex-linked character. The normal colour, red is dominant over white. If a homozygous red eyed female is mated with a white-eyed male, all F_1 progeny is red-eyed, the F_2 contain 2 red-eyed females, one red-eyed male and one white-eyed male. The sex-linked character is thus transmitted by every egg but by only half the sperms. The sex-linked characters have their genes located in the X-chromosome. Linkage is not always complete, sometimes it is only partial. Characters that were together thus become separated. Such a case is known as ***cross-over***.

Ancestral inheritance. GALTON (1882-1911) stated that two parents of an animal contribute one-half of the total inheritance. The four grandparents contribute one-quarter, the eight great-grandparents one-eighth, the sixteen great-great grandparents one-sixteenth and so on. This means the resemblance of an animal to its ancestor diminishes with increase of remoteness of the ancestor. The offspring therefore resembles more the immediate parents than the remote ones.

3. ORGANIC EVOLUTION

What is organic evolution? Organic evolution deals with the changes that have taken place in organisms. The doctrine of organic evolution states that the existing organisms are the modified but lineal descendants of those that lived in the past. New species of animals arise by gradual modifications of existing forms. Animals are constantly changing and becoming better adapted. In course of time they change so much that they are not what they were at the start. In the early periods of life, animals were much simpler than even the amoeba. From these simple types arose the complex protozoans, which gave rise to the Coelenterata. The Coelenterata gradually evolved into segmented worms and Arthropods. Some of these ancient Coelenterates changed in another direction and gave rise to the ancestral Chordata, that later evolved the vertebral column. Then the fishes appeared. Some of them crawled on the swampy and marshy ground and began gulping air. At this stage great changes took place. These pioneers had their lobed-fins modified into limbs. They thus became Amphibians. After them came the reptiles that gave rise to both birds and mammals.

The doctrine of evolution is thus opposed to the older theory of special and separate creation of each animal, as is expounded in the religious books of various peoples. There is not one single evidence for the special creation but all evidence supports the idea of organic evolution.

History of Evolution theory.—The theory of organic evolution is not of recent origin. Early Greek philosophers had vague notions of an evolutionary process. Aristotle (384-322 B. C.) already had definite ideas regarding evolution. He believed in a progressive development of the animal kingdom out of the simplest beings created by God. Buffon (1707-1788) was the first biologist who discarded the idea of special creation and immutability of animals. He concluded that animals are plastic and change and modify continually. Lamarck (1744-1829) proposed the first theory of Evolution. Darwin (1809-1882) adduced evidence for evolution and was responsible for its general acceptance. In Hindu mythology the idea of evolution underlies the *avatars* of god. *Matsyavatar* or the fish was the first incarnation of God. Then followed *Kurmavatar* the reptile. This was succeeded by *Varahavatar* the boar or the primitive digging mammal. The next *Vamanavatar* represented pigmy anthropoids. *Parasuramavatar* involved the primitive man, a hunter symbolized by the axe. *Ramavatar* marked man, an ideal son, ideal brother, king and so on.

Krishnavatar and *Budhavatar* represented refinement of mankind. The idea of continuity and oneness of all life pervades Hindu philosophy. The irreversibility of evolution enunciated by DOLLO, is also contained in the idea that the soul having at long last reached the human body, does not go back to other lower bodies.

Evidence for Evolution.

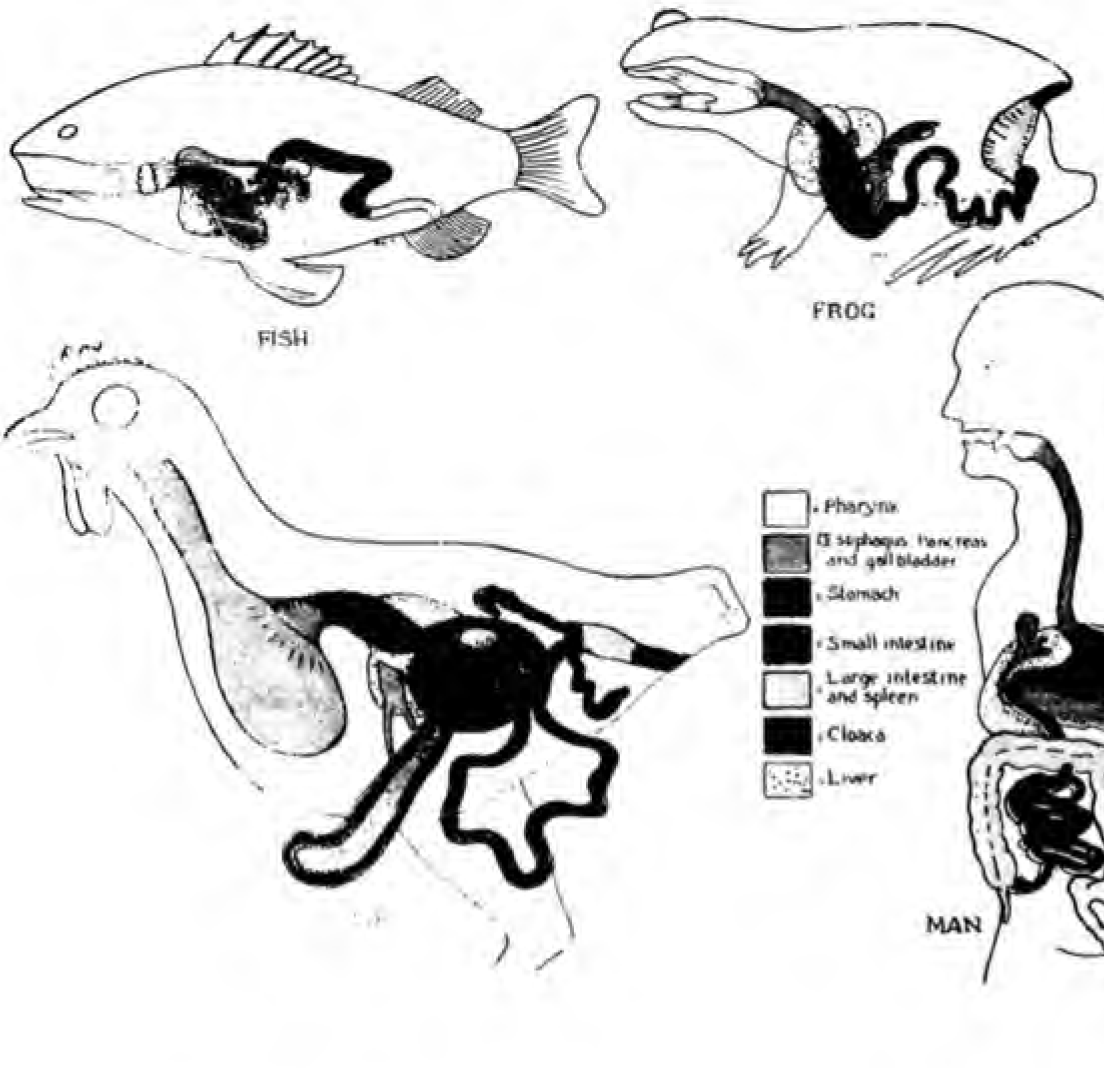
Evidence for evolution is derived from 1. classification, 2. connecting links, 3. comparative morphology, 4 vestigial organs, 5. embryology, 6. atavism, 7. palaeontology, 8 missing links, 9. zoogeography, 10. changes under domestication. 11. mutations and 12. physiology and experiment.

Classification.—In classification animals are arranged in an ascending series of complexity based on structural resemblances. All chordates, for example, have certain common characters and can be arranged in a graded series as fishes, amphibians, reptiles, birds and mammals. The amphibians resemble fishes most and pass imperceptibly into the reptiles. The reptiles again merge into the birds and into the mammals. The mere fact that it is possible for us to arrange the animals in a *geneological tree* in the natural classification strongly supports affinity of animals by lineal and common descent. Were not this so, the resemblance of amphibia to fishes, that of reptiles to amphibians and so on is wholly meaningless.

Connecting links.—Some animals bridge gaps between two groups of animals and thus constitute *connecting links*. The Dipnoi or lungfishes are intermediate between the fish and amphibian. *Peripatus* similarly bridges the gap between Annelida and Arthropoda. The Monotremata like *Tachyglossus* and *Platypus* (Fig. 364) connect the mammals with the reptiles. Such intermediate or transitional forms are relics of the past that have survived and indicate the path along which the fishes became modified into amphibia or the reptiles into mammals. The existence of such transitional forms is a very strong evidence for evolution.

Comparative morphology.—The members of a group of animals are constructed fundamentally on the same plan of structure. Series of corresponding organs are only slightly modified according to different functions or modes of life. The limbs of the Vertebrates, for example, are built on the same essential plan (Fig. 476). They contain in all of them the same bones but the bones differ in proportions in different animals. They are thus differently modified and specialized for different modes of life such as swimming, walking, jumping, flying, climbing, digging, etc. A

PLATE IV.



Evidence of comparative morphology. The digestive tracts of the fish, frog, fowl and man comprise the same essential parts. Differences are only of proportions.

similarity of plan cannot run through such a varied series if all the different forms were not derived by modifications of one common generalized ancestral type. Practically every organ system presents such resemblances among the vertebrates. The alimentary canal (pl. iv), nervous system, heart, excretory and reproductive systems are all built on one generalized pattern. They show progressive changes from fish to mammal. The brain for

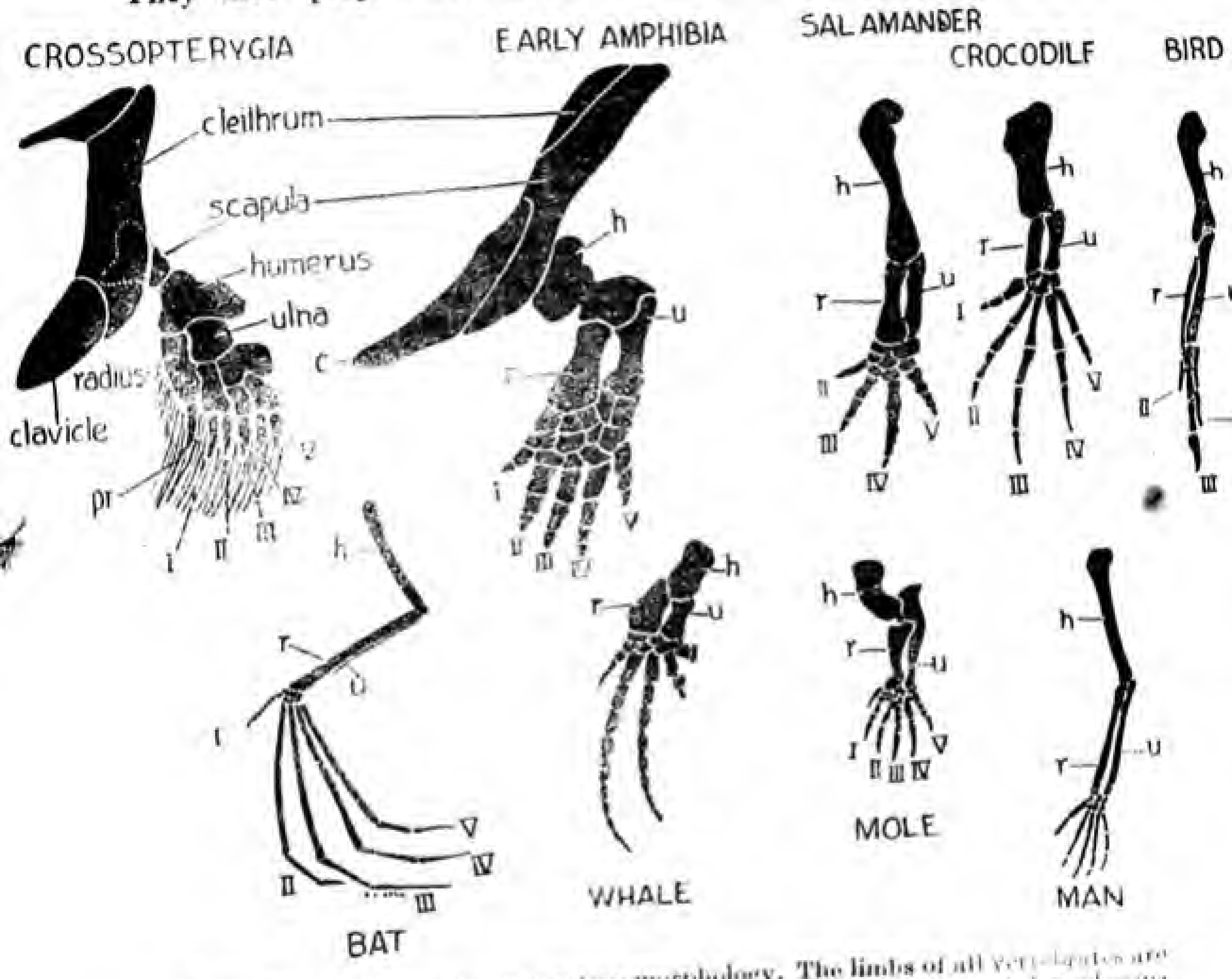


FIG. 476. Evidence of comparative morphology. The limbs of all vertebrates are built on the same plan and contain the same bones. The hand of man is homologous with the lobed-fin of the air-breathing Crossopterygian fish. The limb differs in early Amphibia, salamander, crocodile, bird and other animals only in the proportions of the bones. Such a resemblance in the structural plan can only be due to affinity of common descent by evolution.

example tends to enlarge and become more and more complex. The heart is two-chambered in fish, three-chambered in amphibians, incompletely four-chambered in reptiles and completely four-chambered in birds and mammal.

While the wings of bird, bat and Pterodactyl have the same essential plan, the wings of butterfly, grasshopper and mosquito are constructed

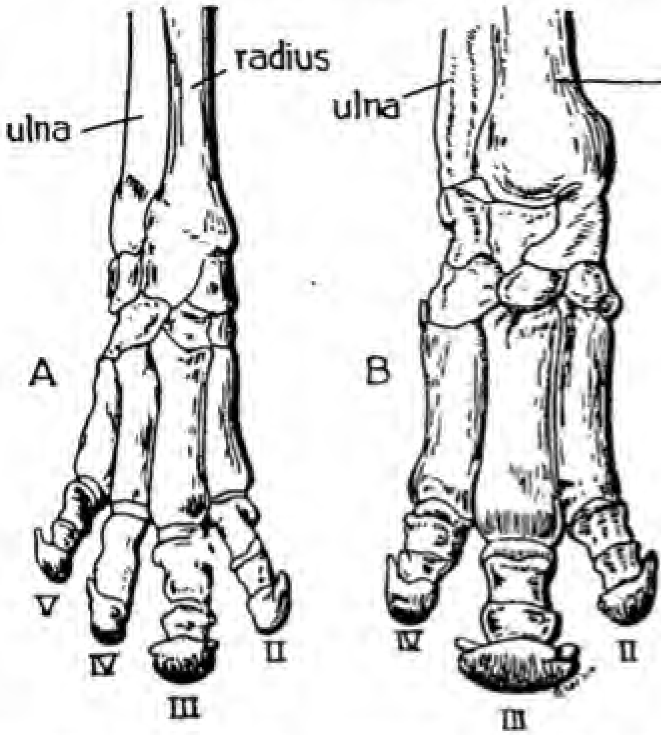


FIG. 477. Evidence of comparative morphology. The limbs of A. tapir, B. rhinoceros, and C. horse are built on the same skeletal plan: they contain the same bones. Specialization has resulted in reduction of some and fusion of other bones. (From *Richard Hertwig, Lehrbuch der Zoologie, Gustav Fischer, Jena*).

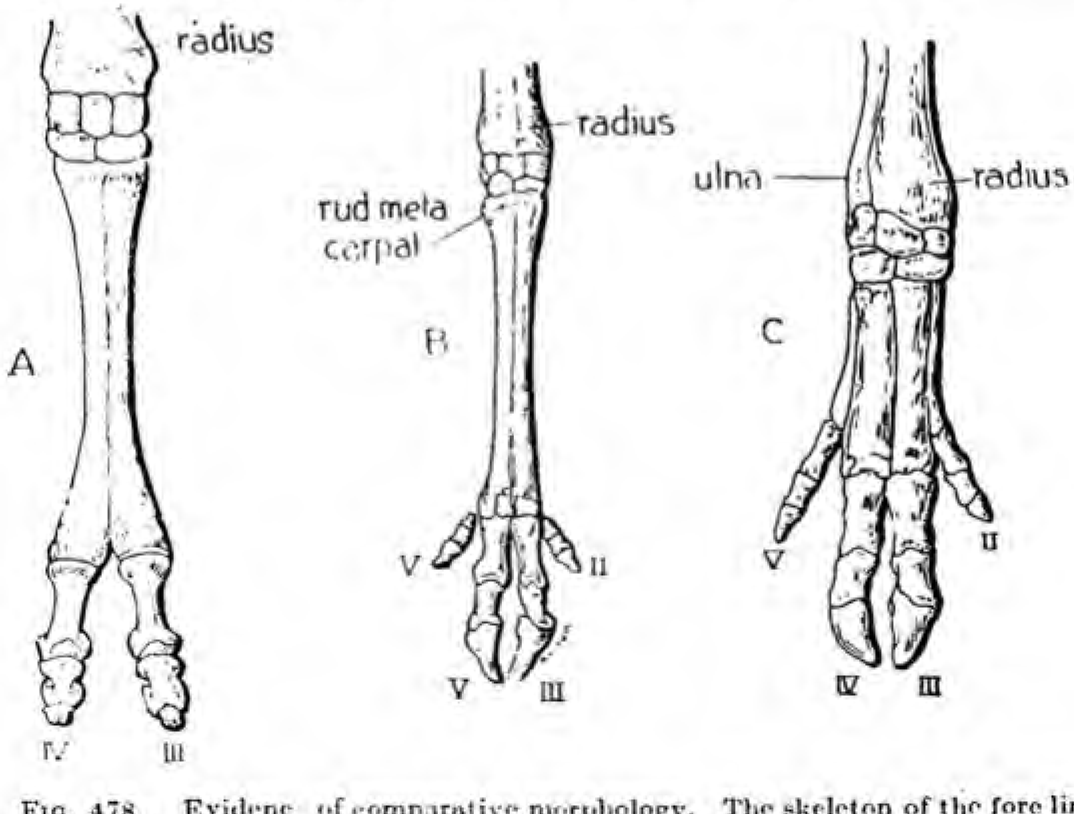


FIG. 478. Evidence of comparative morphology. The skeleton of the fore limbs of A. camel, B. deer and C. pig. (*From Richard Hertwig, Lehrbuch der Zoologie, Gustav Fischer, Jena*).

on quite an entirely different plan. The first series of animals must have descended from one common ancestor and have thus inherited one plan of organization. The second series of animals have similarly descended from another common ancestor and have therefore another plan of structure. The skeletal elements in the wings of bat, pterodactyl and birds are ***homologous***, because they are modifications of a common pattern of fore limbs. The wings of insects are only ***analogous*** to those of bird

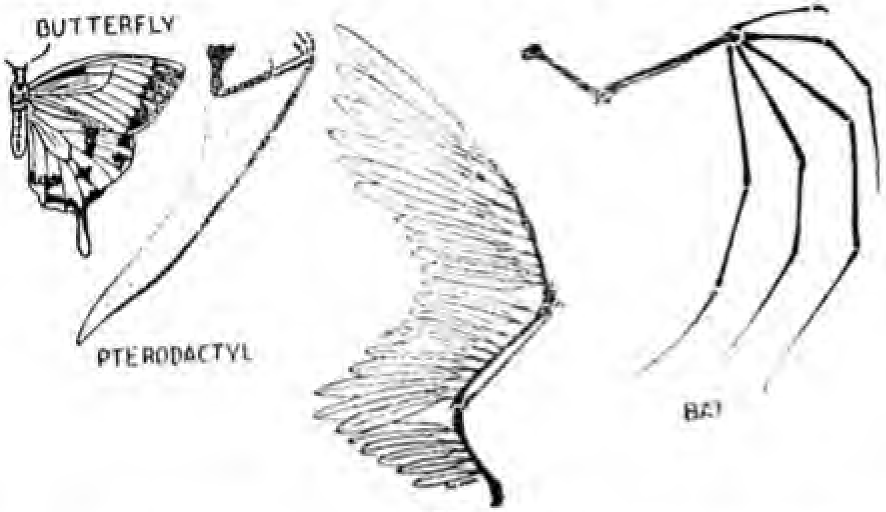


FIG. 479. Evidence of comparative morphology: Homologous and analogous structures. The wings of the extinct Pterodactyl, the bird and the bat are the modified fore limbs: they are homologous structures and thus have a common origin. The wing of the butterfly is not a limb but an expansion of the body wall. It has the same use (function) as the wing of bird or bat, with which it is analogous. The butterfly is thus descended from an ancestor different from that of the pterodactyl, bird and bat.

and bat. Though similar in function, they have different origins. The mouthparts of insects differ much in cockroach, locust, bedbug, butterfly, bee, lice, and fleas. They are however constructed on the same plan and are only modified and specialized by elongation of some parts and reduction of other parts in the different insects as adaptations for their different modes of feeding. Similarity of plan of structure is one of the strongest proofs of descent with modifications, in other words evolution.

Vestigial organs.—Vestigial organs are structures that are found in a reduced condition and serve no function. They however resemble and correspond to the same organs useful in other animals. Many flightless birds like emu, cassowary, rheas and ostrich, have vestigial wings. In the housefly and mosquito the halteres are the vestiges of the hind wings. Cave-dwelling animals have very small eyes hidden under the skin. Traces of the pelvic girdle and hind limbs occur in whales (Fig. 480). Normally snakes are

limbless but in pythons (Fig. 480) the vestiges of the pelvic girdle and hind limbs are present under the skin. The so-called "claw" of the python is a vestige of the hind limbs. In most snakes only the left lung is developed but in some the vestigial right lung is often found. The fore and hind limbs of the horse (Fig. 477) have buried within the flesh splints of vestigial metapodials on either side of the stout middle toe In man there are ninety

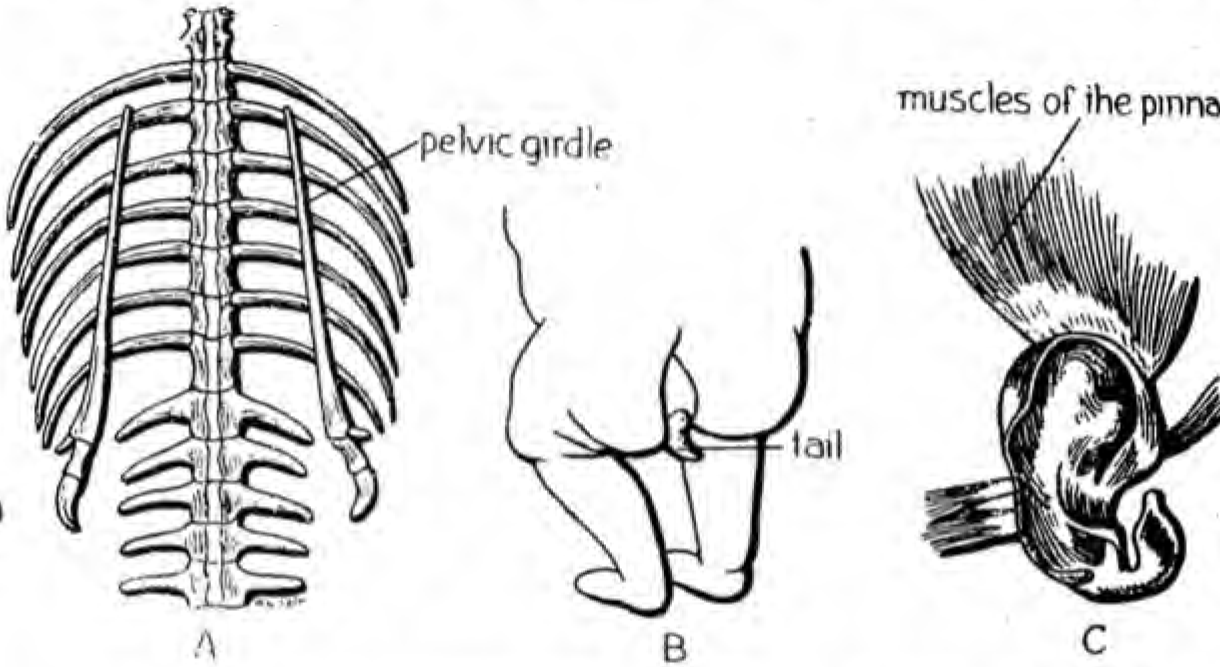


FIG. 480. Evidence of vestigial organs and atavism. A. Vestigial hind limbs of python. B. Occasional vestigial tail as an atavistic feature in a newborn human baby. C. Vestigial muscles of the ear pinna, quite useless, in man. (*After Romanes, "Darwin and After Darwin", Open Court Publishing Co.*).

vestigial organs; the vermiform appendix is one of these. The ear pinna is moved by special muscles in mammals. In man the pinna (Fig. 480) is not movable and muscles are vestigial. The coccyx of the human skeleton is another example. The existence of vestigial organs cannot be explained unless it is admitted that being useless they are disappearing. The animals are thus gradually changing and becoming modified.

Embryology.—Metazoa begin their development from the zygote, form blastula, gastrula and then become differentiated in various ways The zygotes of vertebrates undergo segmentation differently according to the amount of yolk present but the early embryos of all are alike (Fig. 484) and cannot be distinguished one from the other. Later each class becomes recognizable, still later the family and genera become distinct. The fish embryo develops paired gills, gill slits and aortic arches. These persist in

the adult.) Similar structures appear in the frog embryo. When the tadpole metamorphoses into the frog, the gills and gill slits disappear and the aortic arches are modified (Fig. 482) to serve the three-chambered heart of the adult. The embryos of all reptiles, birds and mammals including man

FIG. 481. Evidence of embryology for evolution. The ten [illegible] human embryo resembles a fish embryo. Like the fish it has a [illegible] there is no yolk. This can only be so if man is descended from a [illegible] ancestry. (*Original photograph of a specimen loaned by Mr. D. S. Chowdary,* [illegible] *Thomson Medical College, Agra.*)

(Fig. 483) develop a fish-like pattern at first. They possess the two-chambered heart, aortic arches, gills and gills slits exactly as in the fish embryo, though as adults none of these animals have these characters. The embryonic gill slits close, the aortic arches become modified into the

carotid and other arteries and the heart becomes three-chambered and then finally four-chambered in birds and mammals. The cartilagenous gill arches that form in the embryos of the fish, amphibia, reptile, bird and mammal remain as gill arches in the fish but become modified as jaws and hyoid apparatus in the rest. All these can indicate only one thing: the amphibian, reptile, bird and mammal are descended from a fish-like aquatic ancestor. During the embryonic development, each of these animals thus passes through all the modifications that the ancestor went through during the long course of evolution. Embryonic development or ***ontogeny*** is thus a brief *recapitulation* of the development of the race or ***phylogeny***. It is almost an abbreviated edition of phylogeny—evolution. These ideas were formulated by a German biologist, ERNST VON BEAR (1792-1876) as ~~below~~: 1. general characters appear before special characters, 2. from the more general arise the less general and finally the specialized characters, 3. during its development the animal departs progressively from the form of others and 4. the young stages of animals are like the embryonic stages, but not like those of the adults, of other animals lower in the scale. Another German biologist and philosopher, ERNST VON HAECKEL (1834-1919), formulated the well known ***biogenetic law***: individual animal in its ontogeny tends to recapitulate the stages passed through by its ancestors (phylogeny). Ontogeny is not always however an exact replica of phylogeny; many stages are suppressed or shortened and "two-step leaps" are taken or new modifications are introduced. The recapitulatory stages are often blurred but on the whole ontogeny may be compared to a "two-hour" cinema show of an event that took two decades. We thus actually see evolution projected for our benefit in the embryonic development of an animal.

Atavism.—Atavism is a sudden reappearance of an ancestral structure that has been completely lost. The canine teeth become excessively developed in men on rare occasions. Similarly profuse hairy growth appears on human face. Occasionally babies (Fig. 480) are born with a small tail. Atavism can only be explained on the basis that these structures were present in the ancestors but have been lost in the course of evolution.

Palaeontology. The succession of fossils is really a record of evolution. The successive forms of animals that arose one after another became preserved as fossils, indicating the path of evolution. Indeed fossils tell the story of evolution. Fossil record has however many imperfections and is rarely ever complete. It is like an old and torn book that lacks the first few chapters, contains pages here and there in the middle, often destroyed by white ants, with the writing faded and illegible, but towards the

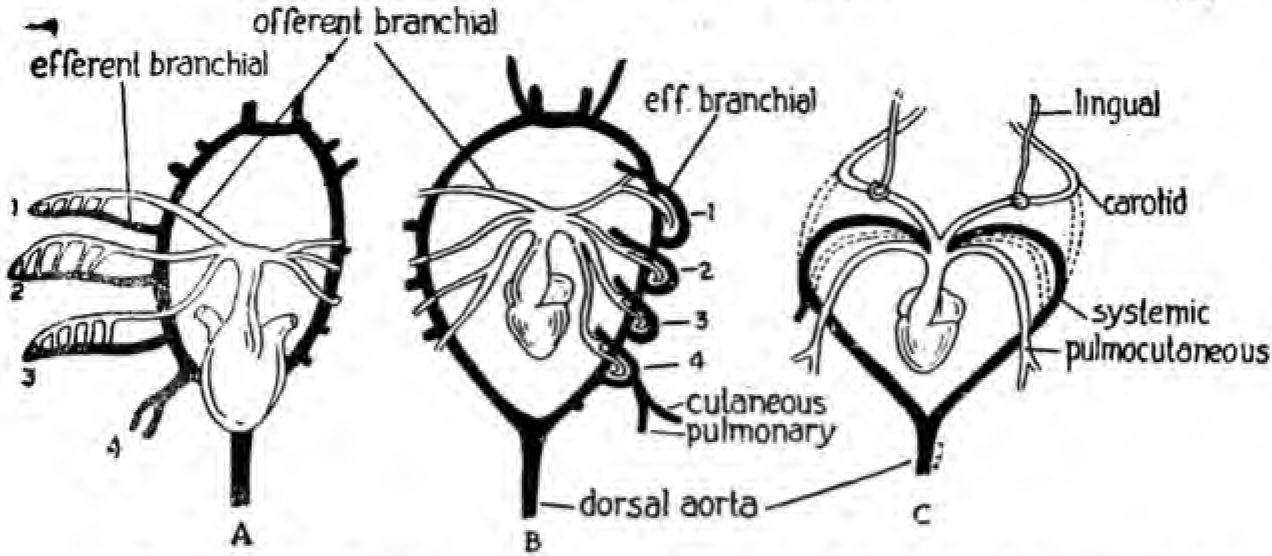


FIG. 482. Evidence of embryology. Diagram of the circulatory system of the frog's tadpole A. with external gills, B internal gills and C. of the adult frog. There is an actual recapitulation of the successive stages in the evolution of the circulatory system of the adult frog from that of a fish.

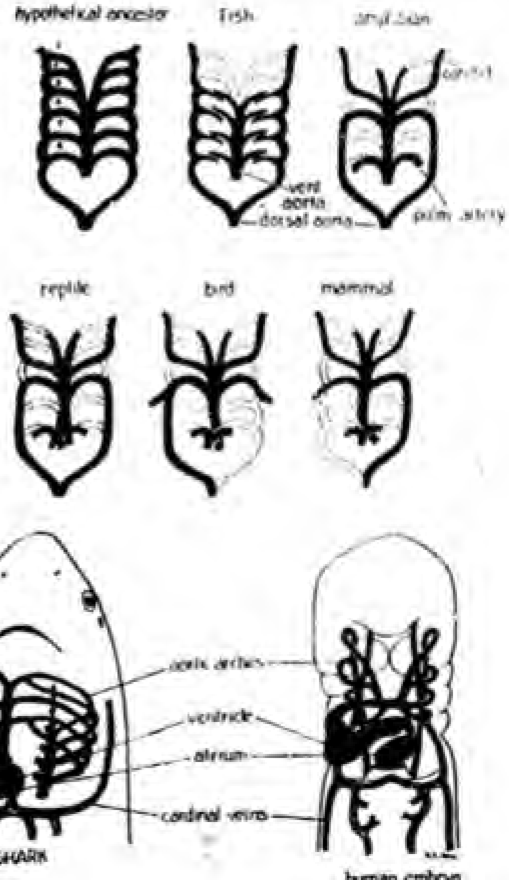


FIG. 483. Evidence of comparative morphology and of embryology of the circulatory system of the Vertebrates. The blood vessels that have disappeared during evolution are shown in dotted line. The circulatory system of a 3 mm. long human embryo is identical with that of a shark fish, complete with gill slits, gill arches, etc. though man never has gills.

end more and more complete and better preserved. Despite these defects the story can be pieced together.)

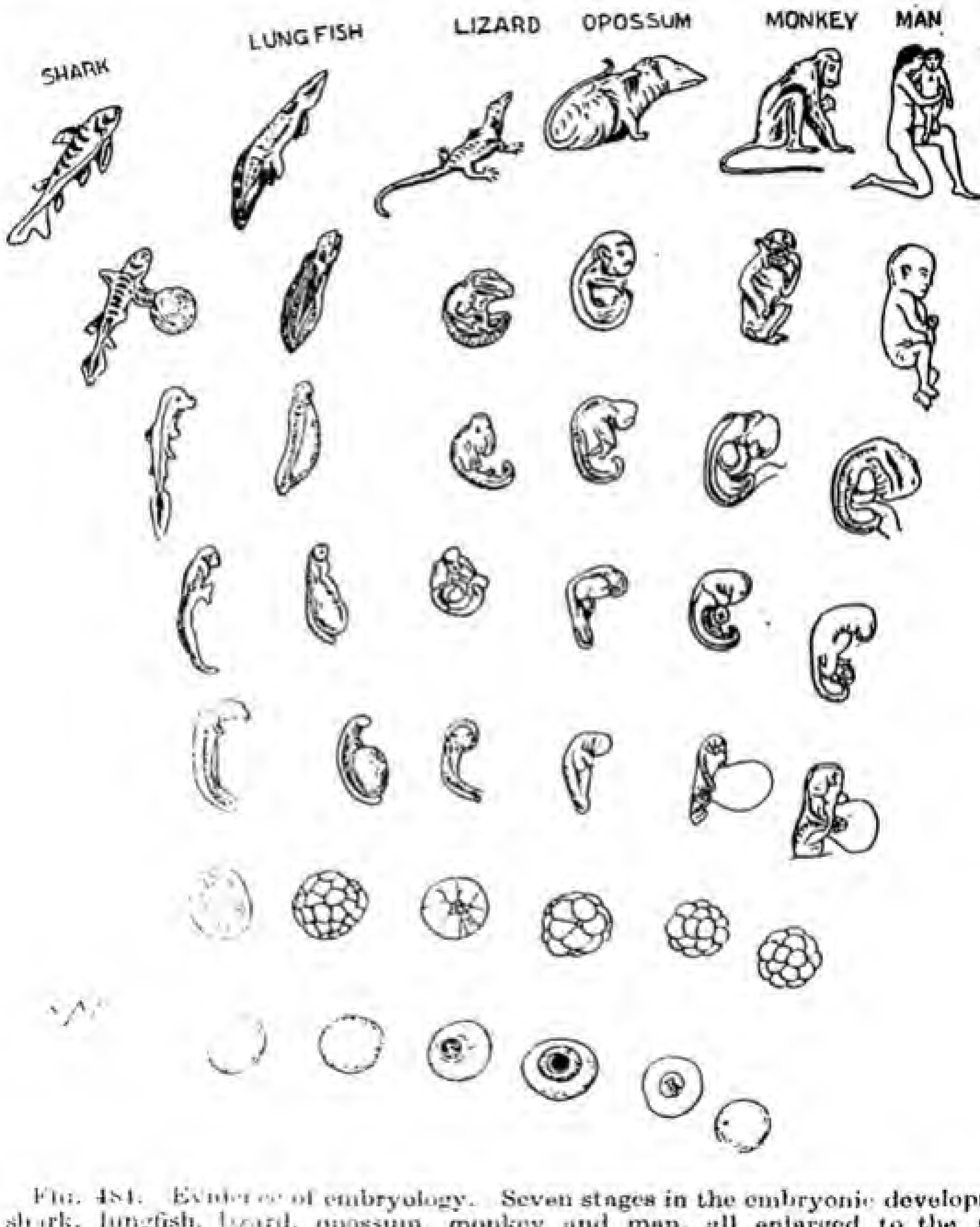


FIG. 481. Evidence of embryology. Seven stages in the embryonic development of shark, lungfish, lizard, opossum, monkey and man, all enlarged to the same size, illustrate the zygote, the cleavage, the beginning of body segmentation, the appearance of gill slits and fore limbs, the late embryo, the foetal embryo or larva and the adult. The early embryos are indistinguishable one from another. The early human embryo is a fish: like the fish it has the yolk sac and gill slits. It passes successively through the lungfish, lizard, opossum and monkey stages before becoming definitely human. Why should this be so if man is not descended from a fish-like ancestor. (*Modified from Gregory, Courtesy of the American Museum of Natural History*).

The first fossils were all marine and were invertebrates Later the primitive chordates appeared. Sharks with jaws and fins appear in the Devonian (Fig. 473) and fishes in the Silurian. The amphibians gain ascendency in the Carboniferous. From the Permian to the Cretaceous the reptiles dominate. The first mammals appear in the Triassic but actually become dominant only in the Eocene.

In some cases the fossil record has been so exceptionally well preserved and complete that the entire evolutionary progress can be easily reconstructed. This for instance is the case with the horse and elephant. Horses are descended from the small four-toed *Eohippus* that was no taller than a rabbit. By successive stages it became a three-toed larger animal and finally the one-toed modern horse.

The elephant began as a small hare-like animal, *Moeritherium* (Fig 485), about 2 ft. high. It flourished in swamps in Egypt during the Eocene Epoch *Moeritherium* gave rise to *Palaeomastodon* during the Oligocene. *Palaeomastodon* stood 42 inches high. The second incisors of the upper and lower jaws were enlarged into tusks and the upper lip was enlongated to reach the ground. The animal dug succulent roots, bulbs and other underground parts of plants for food. During the Miocene *Palaeomastodon* changed into *Trilophodon* that stood 82 inches high and migrated into Europe, Asia and America. The two lips lengthened out. The two showel-shaped lower jaw teeth were employed in digging. *Trilophodon* gave rise to various kinds of mastodons like *Dinotherium* and *Stegodon*. The latter arose during the Pliocene and was 91 inches high. These animals now took to feeding on grass and other similar vegetation rich in silica. The food thus rapidly wore off the teeth and as an adaptation they became hardened by increase of transverse bars. The head became massive to support such large teeth; the body and legs became in turn massive to support such a head. The lower tusks reduced but the upper tusks continued to elongate. The elongated upper lip served for reaching the ground in drinking water and therefore continued to elongate into the trunk. When these gradual modifications became complete in the Pleistocene Epoch, various species of elephants were born: *Elephas imperator*, *E. primigenus*, *E. ganesa*, *E. indicus*, *Loxodontia africana*, etc. Only the last two have survived to the present day. Fossil record thus conclusively proves that the ~~elephants~~ horse are descended from *Moeritherium* by gradual modifications and adaptations of structure from swamp-dwelling to forest-dwelling. The evidence of palaeontology is therefore direct and absolutely final.

Missing links.—A missing link is an isolated fossil that fills the gap in the fossil record of evolution of a group. For example, birds appear when

FIG. 485. Evidence of Palaeontology for evolution. The modern elephant is traced back to a small rabbit-like ancestor by a complete series of fossil remains of extinct proboscidians. The fossil record tells the story of a swamp dweller that dug roots gradually transforming into a forest dweller that feeds on coarse grass and leaves. This photograph of a wall case in the Zoology Museum, St. John's College, Agra, contains plaster models of reconstructions of the fossils. It illustrates the steps by which the elephant got its trunk.

the dominant reptiles became extinct during the Cretaceous. Some extinct reptiles were very much bird-like. Between the bird-like reptiles and

the reptile-like birds of the Cretaceous there was a gap. This gap was filled up by the discovery of fossil remains of the toothed lizard-bird, *Archaeopteryx lithographica* (Fig. 486), in the lithographic slate of the Jurassic Period (Fig. 473). This bird was about the size of a crow and had a long tail with caudal vertebrae, teeth in the jaws and three free fingers and claws in the wings. It thus represented a transition stage in the modification of the fore limbs of a lizard-like ancestor into the wing of a bird. *Archaeopteryx* therefore constitutes a missing link, that fits in and completes the story of evolution of birds.

FIG. 486. *Archaeopteryx lithographica*, the extinct lizard-tailed Jurassic bird is a classical example of missing link. It bridges the gap between reptiles and birds and marks a transition stage. (*From a reconstructon in the Zoology Museum, St. John's College, Agra*).

Zoogeography.—The present distribution of animals on the earth is exactly what should be expected on the basis of evolution. An older group of animals is more widely distributed than a younger group. Moreover, geographical barriers isolate groups of animals and give rise to new forms. The existence of certain primitive animals as relics of the past, as for example, in Australia and South America, is due to preservation of these forms by isolation. In areas where isolation is absent, the ancestors evolved into the higher forms. If evolution did not take place, the peculiarity of the fauna of Australia, for example, cannot be explained.

Changes under domestication.—Man has domesticated various animals, like dog, cat, horse, cattle, fowl, pigeon, etc., which differ so much from their wild forms that they can be actually called different species. Man has evolved with his own hands new animals from old. The various varieties of cats, fowl and pigeon are all descended from wild ancestors. The fact that man can produce evolution is strong proof that it does take place in Nature.

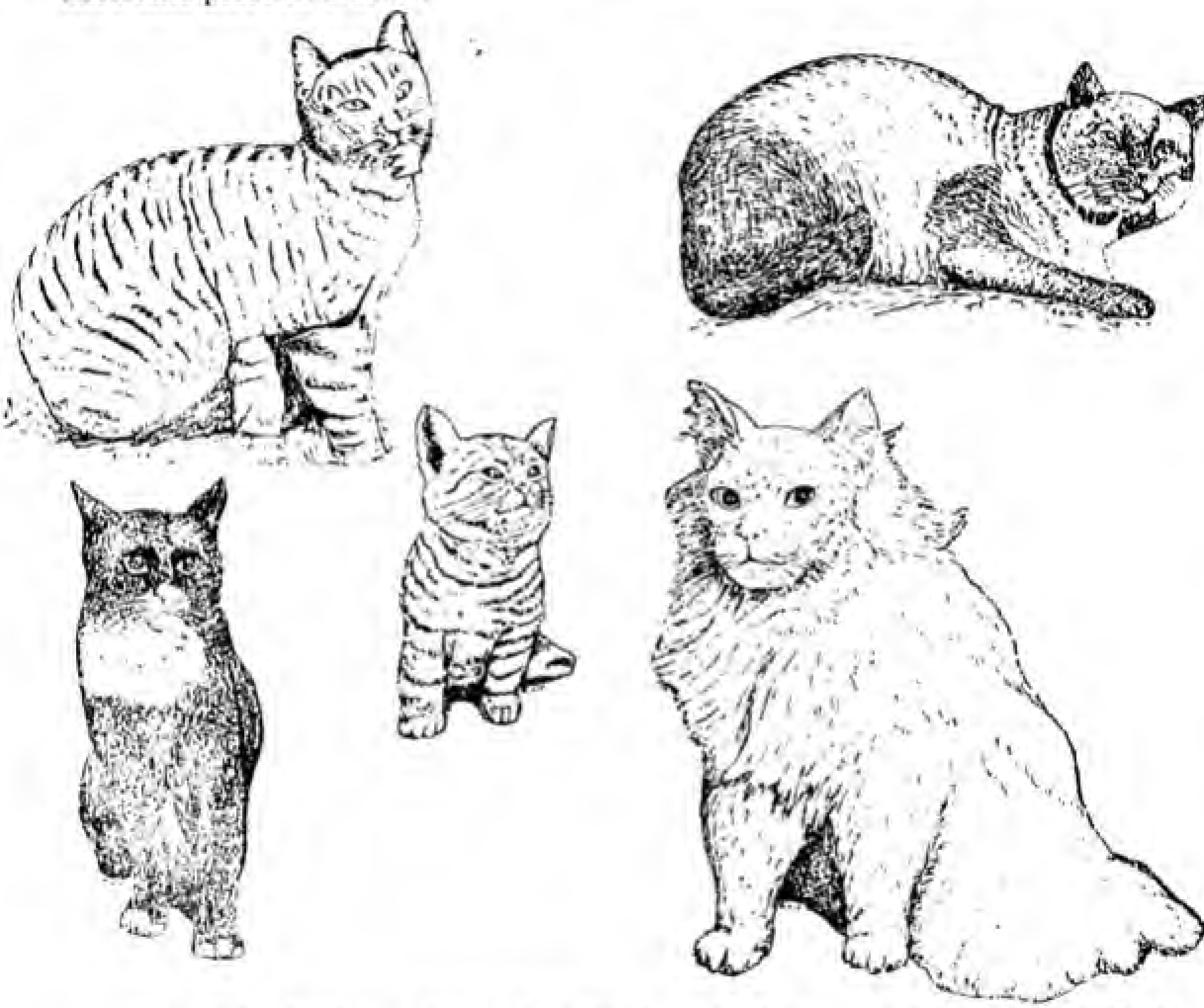


Fig. 487. Evidence of animals under domestication. The innumerable varieties of [illegible] cat are results of artificial selective breeding and domestication by man. They are descended from the wild cat. (*Redrawn from Davenport.*)

Mutations.—Mutations are new forms of animals that appear all on a sudden and continue to reproduce their kind. Such mutations have been observed in many animals like, *Drosophila* the bananafly (Fig. 490). They have also been artificially produced by the action of X-rays. Mutations strongly support the idea that animals modify and transform into others.

Physiology and experiment.—As affinity of animals can be established by structural resemblances, physiology also helps us to do the same. Fresh

human blood serum injected in minute doses into a rabbit causes the formation of an antibody in the latter. If the "antihuman" serum of the rabbit is now added to human blood serum, a white precipitate is formed. A si milar result is obtained by the "antihuman" serum of rabbit with blood of monkey, but not of donkey, horse, dog or cow. This shows the direct affinity of monkey and man. Experiments have been so extensively carried out on these lines that it is quite possible to indicate what animals are related and what are unrelated. Further, the malarial parasite that develops in human blood and causes malarial fever in man, can also do the same in apes and monkeys but not in other animals. The affinity of man and monkey can only be explained on the basis of evolution from a common ancestor.

Methods of Evolution : Evolution Theories

The theories regarding the exact method by which evolution is brought about include: 1. Lamarckism, 2. Darwinism, 3. Mutation theory, 4. Hybridization theory and 5. Orthogenesis.

Lamarckism. The first general theory of evolution was proposed by JEAN BAPTISTE LAMARCK (1744-1829) (Fig. 453) in 1809 in his "Philosophie Zoologique". His theory, known as ***Lamarckism***, has been much misunderstood by biologists. Even to this day text-books misinterpret Lamarck's ideas regarding the exact method of evolution.

Lamarckism states that environment has a profound influence in shaping animals. When the environment changes or when the animal comes to live under a different environment, it encounters new needs. This occasions new habits in the animal. Change of habit involves extra use of some organ or less use or disuse of others. Structures that are used more develop more and permanent disuse weakens and reduces others to mere vestiges and causes their final disappearance. The habit, structure and organization of the animal are thus modified. Characters which the animal developed as adaptation for changed environment or ***acquired characters***, as they are called, are temporary and not inherited by its next offspring. The animal has however become attuned to the stimulus that caused the acquired character. This attunement endures longer than the character. If the stimulus is repeated, the animal responds quicker and better than at first. The attunement is inherited by the offspring, so that the acquired character develops earlier and more easily in successive generations, until finally it appears in the embryo itself. Different habits contracted early and long persisted in alter the structure of the body. The offspring of such altered animals, exposed to the same influences,

acquire the parental habits earlier and more and more easily than the parents. A sort of "habit memory" persists and increases from offspring to offspring. After the changed habits have persisted for a long time, the changed structure appears on very slight stimulus. At long last it appears even without the external stimulus: the structure thus becomes inherited. Environment thus does not act directly on animals, but by producing new needs, to which the animal responds by fresh efforts. These efforts lead them to use some organs more and others less. Those that are more used increase in size, whilst those used less diminish. It is thus use and disuse continued over long stretches of time that eventually lead to structural modification—evolution. Lamarckism may be summarized thus: 1. changing environment creates new needs, 2. changed needs create new habits, 3. new habits involve use and disuse of structures, 4. use and disuse of structures lead to structural modifications, 5. the acquired habits are inherited by the offspring, 6. the structural modifications arise earlier and earlier in successive generations until they are finally inherited.

When the ancestral fishes began to crawl on land, for example, they met with environmental conditions totally different from water. They had to breathe air, had to support their body and crawl on the lobed-fins, see things in air and so on. They gulped air and retained it in the throat, the gills were less and less used and the eyes were focussed on distant objects. Lungs gradually grew as pouches from the throat for filling more and more of air. The gills began to shrivel up by disuse. The lobed-fins gradually enlarged, elongated and modified into limbs by the extra use. The lens of the eye became flatter. These modifications gave rise to the Amphibia.

The swamp-dwelling *Moeritherium* migrated to drier regions and took to eating grass. These changed habits modified their teeth, these in turn the skull and again in turn the rest of the body until finally the elephants came into being. *Eohippus* (=*Hyracotherium*) of the Eocene had four toes on the fore feet and three on hind feet. Its environment gradually changed into open plains rich in grass. Such a habitat necessitated speed as an efficient means of defence and high strong teeth for grinding the harsh grass. Speed is gained by quicker swinging of the leg and longer strides. The legs of an animal behave like a pendulum. As in the latter, shortening the leg increases the frequency of the swing. The femur thus shortened but the foot elongated and the animal ran "tiptoe" on the nail of the third toe and increased the

stride. The side toes did not reach the ground and soon came to be lost, the animal was left with one toe. These gradual modifications resulted in the horse.

Controversy about Lamarkism.—AUGUSTUS WEISMANN, a German naturalist, however denied Lamarckian ideas of step-by-step change. He was also largely responsible for the misinterpretation of Lamarckism. Weismann maintained that acquired characters are not inherited. Only those modifications that affect what he called *germplasm* are inherited. "Acquired characters" are changes in the *somatoplasm* or protoplasm of the body, as distinct from that of the germ. The body perishes but only the germs—ova and sperms—survive ; changes to these can alone be inherited. Bodily modifications do not affect the germ. In proof of this, Weismann cut off the tails of generations of white mice and bred tailed mice from these mutilated ones. He then triumphantly claimed to have disproved Lamarck !

The progress of biological science has however been fatal to Weismann's theory of germplasm. While it is true that the germ cells are set apart early in some short-lived animals, there is not any differentiation of germ cells and body cells in most others.

In the Vertebrata, for example, the germ cells appear early in the embryo and undergo the typical maturation-division, but soon degenerate and disappear completely as the animal grows. The germ cells that actually give rise to the ova and sperms develop later from the peritonium—out of the somatic cells. A hen that had laid many broods of eggs began to assume the appearance of a cock and fertilized hens. CREWE found that the ovary of this hen had been destroyed by disease, but a testis developed from the peritonium that lines the body cavity. HANS DRIESCH, another great German Biologist, attacked Weismann's view in another way. Each of the blastomeres of the Echinodermata should, according to Weismann, give rise only to a particular part of the embryo. Driesch showed that each of the blastomeres, if shaken apart, developed into a complete embryo—he experimentally produced several embryos out of one egg.

SPEMANN and LEWIS have also disproved Weismann. The eye of the vertebrates is essentially a specialized part of the brain : a retina of photo-receptor nerve-endings on which a lens focusses the light rays. The lens is developed from the skin during the embryonic growth. Spemann and Lewis cut off the rudiment of the retina from a tadpole, in which the lens had not yet grown. They implanted this rudiment under the shoulder. After this surgical operation, the tadpole was let off. The retina now forced the skin of the shoulder to develop into a lens, so that an eye was formed on

the shoulder: a thing that never took place in the whole history of the chordata. It is to be concluded therefore that there is no vital difference between the so-called somatoplasm and germplasm: one can give rise to the other. Germplasm does not exist, as distinct from somatoplasm.

Numerous recent discoveries cannot also be explained except on the basis of inheritance of "acquired characters".

Continual pressure and friction hardens and thickens the human skin. The "corn" for example is the result of such an action. The sole of the human foot is hardened by walking but even the newborn baby's foot is hardened and thickened, though it never walked.

In 1910, SUMNER found that mice reared under warm conditions had longer tail, feet and ear than those raised under colder conditions. These differences, strictly somatogenic according to Weismann, were inherited by the offspring.

KAMMERER'S EXPERIMENTS: The common fire salamander of Europe, *Salamandera maculosa* has black skin with yellow patches. It produces about fifty young tadpoles at a time. The tadpoles later develop lungs and become terrestrial. PAUL KAMMERER kept the mother salamander out of water and compelled her to reproduce on dry ground. The larvae had to be placed in water immediately after birth or they perished. The process was repeated in the next pregnancy. The larvae were now longer and more developed at birth than before. In the fourth pregnancy the young were born with lungs and limbs. This experiment demonstrates that response is progressively quicker and increases with continual repetition of the stimulus.

In another series of experiments Kammerer kept the adult salamander, soon after their emergence from water, in boxes with yellow walls and floor. The animals grew for four years in the yellow surroundings. During this time the yellow patches on the skin increased in size and joined together to form bands. He mated two such animals and found that their young were much yellower than their parents at the same stage of development. He kept another set of salamanders in a black box and found that yellow patches, diminished and in the second generation the animals were black exactly like another species, *Salamandra atra*, that lives in the Alps.

Kammerer also experimented with the midwife toad *Alytes obstertricans*. Toads and frogs lay eggs in water and the tadpoles that hatch from them develop external gills first, later internal gills and finally lungs and limbs. The midwife toad, however, deposits her eggs on land. The eggs are then carried about by the male until the young are

hatched. At the time of hatching, the tadpoles have already passed through the external gill stage and possess internal gills. Kammerer subjected the eggs to heat and dryness. Small tadpoles *with* limbs developed from them. In successive generations fewer but larger ova were laid from which hatched fully legged young. Here again is a progressive increase in efficiency in response to altered environment in successive generations.

The prevailing view of the authorities on evolution at present is that 1 *acquired habits are inheritable* and 2. *structures associated with them*—acquired characters—*are inheritable too.* This does not mean that the acquired character will appear in the next offspring without

FIG. 488 Charles Darwin (1809-1882), proposed the theory of natural selection. He is popularly considered to have completely explained evolution, though his ideas are now no longer accepted. *(Original photograph of a portrait in the Zoology Museum, St. John's College, Agra)*

the stimulus. The young acquire the habit more easily than the parents. After thousands of generations the habit and the structure appear automatically. Lamarckism is thus once again admitted as the method of evolution. It has also the support of palaeontology and embryology.

Darwinism.—Darwinism is the theory of ***natural selection***, that was proposed independently by ALFRED RUSSEL WALLACE (1823-1913) and CHARLES DARWIN (1809-1882), two English Naturalists. Wallace

published his ideas in 1858 and Darwin published his book "The Origin of Species by Natural Selection" in 1859. Because however Darwin presented his ideas in so complete a form and also adduced indisputable evidence for evolution, the theory of natural selection bears his name instead of Wallace's.

Darwinism is based on : 1. over production, 2. struggle for existence, 3. variation and 4. survival of the fittest leading to natural selection.

Every animal has the potentiality for infinite increase. *Paramecium*, for example, passes through six hundred binary fissions annually. If all the offspring survived and continued to reproduce, the total paramecia at the end of one year would occupy a space larger than the earth itself. *Drosophila* (Fig. 490) completes its development from egg to adult in about ten days and each female lays nearly 200 eggs. If all survived we would have in about one month 200,000,000 flies! The elephant reproduces at 30 years of age and gives birth to about six baby elephants. In about a thousand years the number of elephants would exceed 20,000,000. The rate of reproduction of the housefly has already been given (Chapter XIV). Fishes, sea urchins, oysters and other animals produce millions of ova and sperms. If all the eggs of the liverfluke and tapeworm develop into adults, the world will be populated by no other animals but only by these within a very short time.

The high reproductive potentiality is counterbalanced by environmental factors (Chapter XXV). As the available living space and food are limited, very acute competition between animals is the result. There is thus a ***struggle for existence***. The struggle is not only intraspecific and interspecific but also against abiotic factors. The struggle for existence is perpetual and does not exempt any animal, including man. As a result of all these unfavourable environmental influences the vast majority of animals perish and only a very minute fraction of the offspring survive.

Variation is the property of life. Among the numerous variations some are useful in the struggle for existence and others useless. Individuals which possess useful variations have a better chance of survival than those which do not. For example variations occur in size, shape, colour and pattern in animals. An individual in which these variations served to conceal it from its natural enemies would have a greater chance of survival than another not thus protected. The result is the former lives and reproduces and the latter does not. Darwin therefore assumed that there was a sort of a daily "test" in nature in which only the fittest passed. A natural " weeding out " process, which he called ***natural selection***, ensured the ***survival of the fittest***. Some animals were thus ***preadapted*** for a particular environ-

ment. Those that are preadapted survived while those not so fitted are eliminated. The animals that survive hand to their offspring their useful variations, which thus accumulated from generation to generation, until they become so pronounced that the animal is a new species.

Weakness of Darwin's theory of Natural Selection.—It is popularly believed that Darwin completely accounted for evolution by his theory of natural selection. Actually Darwinism is no explanation at all. Experimental and other evidence has also dealt a deadly blow at the idea that natural selection is the main factor that causes evolution.

FIG. 489. Hugo de Vries (1848-1935) a Dutch botanist. He advanced the theory of mutation.

A variation that must be conserved by natural selection has first to be useful and inheritable. Most variations have, however, actually no survival value. They are not at all adaptations but are merely due to the effect of temperature, humidity or other environmental factors. The smallest beginnings of even the adaptative variations would also offer no survival value. A change, for example, in the fore limbs of a reptile toward producing the wing of a bird would be of no use for flight, unless it was large at once. The

protective resemblance of *Kallima* (Fig. 460) has survival value only in the perfected state but when it arose in "small beginnings" could not have had any such value at all. The ancestral forms of *Kallima* could not have survived just because they resembled a dead leaf very slightly. It is also known that it is not always the "fittest" that survives but often the other way

Fig. 490. *Drosophila melanogaster* the vinegarfly, in which over 500 mutants have been studied by Morgan and his pupils.

about. Moreover recent work has shown that animals do not tend to vary far from the average and all such variations rapidly disappear. ***Small inheritable and useful variations do not really exist as supposed by Darwin.*** There is therefore no natural selection also.

Darwinism does not also account for vestigial organs and connecting links. Darwin's theory of natural selection is an unsound one that has failed when tested experimentally.

Mutation theory.—The mutation theory, proposed by the Dutch botanist HUGO DE VRIES (Fig. 489), is a modification of Darwinism. Mutations take the place of small variations of Darwin but natural selection preserves useful mutations and eliminates useless ones. Natural selection theory attempted to explain the *survival* of the fittest but not the *arrival* of the fittest ; mutation theory claims to get over this difficulty. The fittest and the unfit too arrive with a bound without previous notice: not as small useful inheritable cumulative variations but as large useful mutations. According to Hugo de Vries evolution thus takes place by "fits and starts" and is not a continuous and gradual process, that it actually is.

There are however many insuperable objections to this theory. Firstly, mutations are very very rare occurrences and cannot account for evolution on a grand scale. Mutations are "failures from the point of natural selection". Many of the mutants of *Drosophila* described by MORGAN are unfits: shrivelled wings or no wings, defective or no eyes are not characters that have survival value. Mutants are less vigorous, also die more easily than normal forms. Mutations are the result of ***germ-weakening*** and disappear under normal conditions. This is known as ***reversion***. Mutations have therefore nothing to do with evolution.

The term mutuation has had many meanings given to it but we must restrict it to the appearance of inheritable variation. This may take the form of gene mutation or of chromosome mutation. The gene mutations are wholly localized affairs and are never accompanied by simultaneous changes at other loci in the chromosome or in homologous chromosomes. The primary sources of variation include, in addition, increase or decrease, recombinations, misplacements and rearrangements through deletions, inversions, translocations, duplications and reciprocal translocations of genes.

These primary alterations must survive if the species are to be modified by means of them. The genes mostly decide their own destiny, usually *destruction*, by their effect, generally lethal, upon the germ cell that contains the gene mutation. When the two members of a pair are alike there is no particular evolutionary significance. If these are unlike they suggest evolutionary possibilities. In such a case one of the pair is so widespread that it is called the "wild-type" and the other less common—it is a mutation from the wild-type. The character which develops in response to these genes is usually identical with the one which would have appeared if both the genes were of the wild-type. When a gene mutates, its new form is recessive. One wild-type gene, even in the presence of a mutant gene at the same locus, has thus the effect of two wild-types. It has also been shown that one dominant gene is dominant over three recessive genes. The mutant gene can bring its alternative character out only if it is present in both the homologous chromosomes, to the complete exclusion of the wild-type.

Most of the mutant characters that have risen under observation are almost completely recessive. The few of the so-called dominant mutant genes of *Drosophila*, such as those which produce curly wings and star eyes, are of no evolutionary significance, because flies with these characters are incapable of living. Such *Drosophila* mutants actually live shorter, lay fewer eggs and fewer of these eggs complete their development. If mutations are the material of evolution, as claimed by geneticists, evolution must be directed firstly by occurrence of mutations of certain types and not others and secondly by differential survival of these mutations or their differential spread. It has been demonstrated that successive mutations in one direction do not occur and are not indeed possible.

Hybridization.—LOSTY suggested another method of evolution. All animals are *impure* from the genetic point of view and constant hybridization gives rise to newer and newer types by crossing of genetic characters. This involves recombination of genes in Mendelian relation.

Orthogenesis.—According to the theory of natural selection, when a character becomes useless or harmful to an animal, it would disappear. This however is not the case. Animals continue still to vary in this direction, irrespective of the fact whether it is useful or harmful. The antlers of the Irish elk are thoroughly harmful and are in its way of defence and escape. Yet they continue to over-specialize. Such structures are really handicaps. ***Orthogenesis*** explains that the development of a character is a hereditary tendency accompanied by progressive gene changes. The animal develops constantly in *one* direction. Natural selection may perpetuate a type and eliminate an over-developed or over-specialized type.

Cause of evolution.—Except Lamarckism, all the other theories have failed to stand the test of critical examination and experiment. Lamarckism alone satisfactorily accounts for evolution. *It is the inheritance of habits that brings about structural modification* – evolution.

Human evolution: The origin, rise and decline of *Homo sapiens*.—Man has arrogated himself to a central position in the Universe that he does not deserve. The Bible for example made man the centre of creation: man was created by God in his own shape and all else was created for his benefit: the sun was put in the sky so that he may have day, the moon and stars so that his sleepless nights may not be dull! Animals and plants were thoughtfully created to prevent starvation of man.

It was however realized even by ARISTOTLE that man is an animal, that he and they have comparable parts and are generated in the same way. Man's place in the animal kingdom is shown in figure 491. He is one of the chordates that evolved a vertebral column. He belongs to the class Mammalia, order Primates and Family Hominidae.

The story of human evolution begins nearly five hundred million years ago, with the origin of the Chordata from trochophore-like ancestors. The early chordates gave rise to the primitive vertebrates, viz. Ostracoderms of the Silurian and Devonian times. The Ostracoderms lacked jaws and gulped small animals. The next stage was marked by the ancient shark *Cladoselache* (Fig. 493) of the Devonian period. It had a pair of eyes, a pair of nostrils and a mouth with toothed jaws. The eyes were at the sides of the head and the nostrils far apart. The teeth

were spine-like processes of the skin arranged in many rows. It learnt to feed on larger animals.

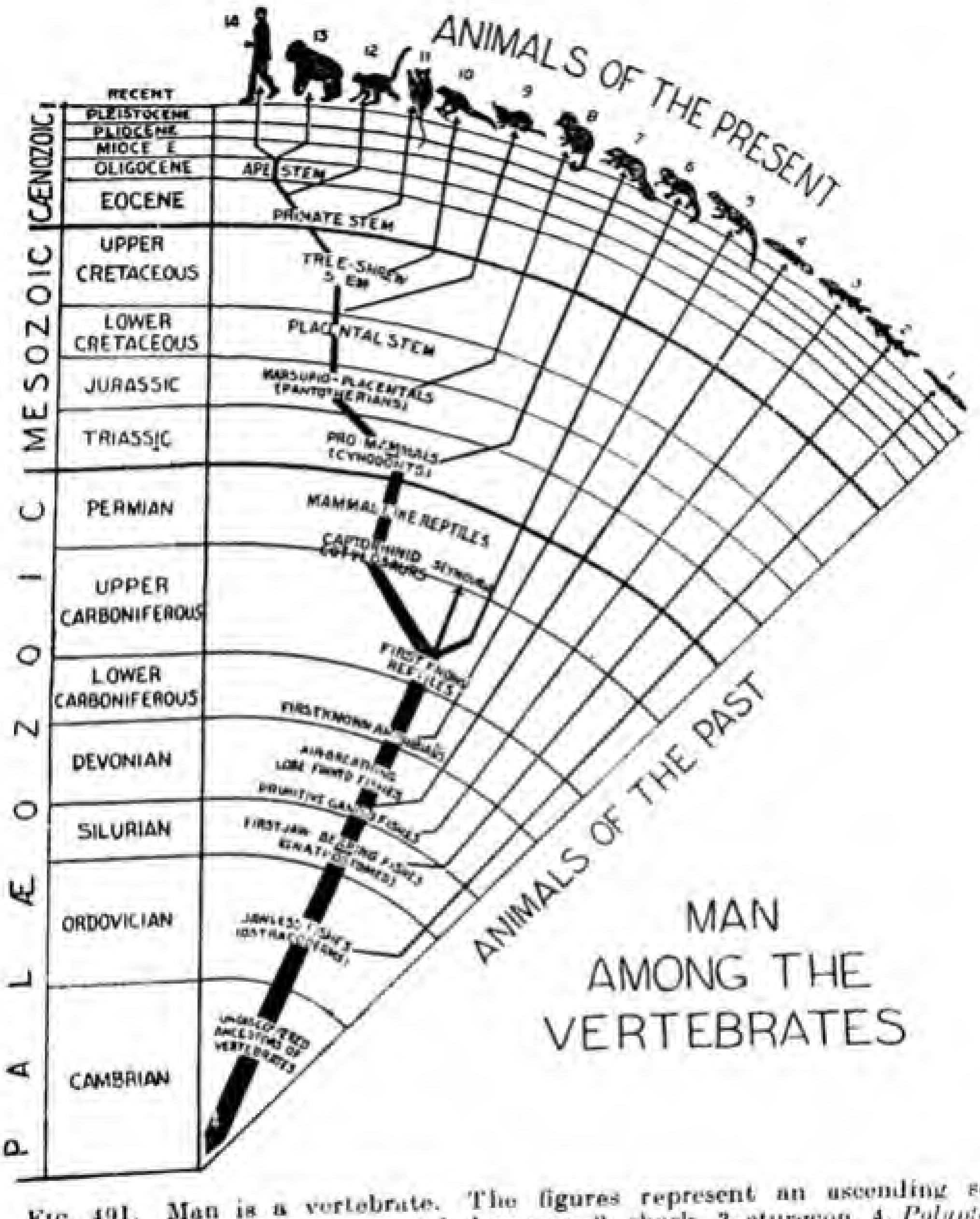


FIG. 491. Man is a vertebrate. The figures represent an ascending series of living animals from shark to man: 1. lamprey, 2 shark, 3. sturgeon, 4. *Polypterus*, 5. newt, 6. *Sphenodon*, 7. *Platypus*, 8. opossum. 9. ground shrew, 10. tree shrew, 11. *Tarsius*, 12. monkey, 13. anthropoid, 14. man. These are not the ancestors of man but are descendents of such ancestors of the past. In each successive geological period, some members progress to the next higher stage but others retain the primitive features. (*Modified from Gregory, Courtesy of the American Museum of Natural History*).

This was succeeded by *Eusthenopteron*, a lobe-finned fish of the Devonian. It represented a step forward to life on land. The nasal cavities deepened and opened into the buccal cavity. Both lungs and gills were present. Its face was a "bony mask" that was pierced by holes

for the mouth, eyes and nostrils. The face was all mouth. The whole set-up had for its object capture of fish; robbing and getting away with the stolen goods and crawling up on the shore to avoid pursuit.

The earliest amphibians mark the next stage. *Eogyrinus*, that flourished in the Lower Carboniferous period, was a swamp-dwelling form. It passed its earlier stages in water just like tadpoles of the frog. The fins became modified into limbs.

Seymouria, an early reptile of the Permo-Carboniferous, took an immense step forward by learning to lay eggs on land. The nostrils came closer together. The rest of the body organization still retained much of the amphibian traits.

The dawn of lower mammal was fore-shadowed by the cynodont reptile *Cynognathus*, in which the eyes began to look forward and the mouth started shortening at the sides. It was a mammal-like reptile that fed on small insects.

The next stage was a reptile-like mammal—a sort of twilight between reptile and mammal. It is represented at the present time by the common opossum, a "living fossil". It is a survival of the past, a relic that indicates what an archaic mammal must have been. The head is produced into a muzzle. The eyes look more in front. An external ear pinna has appeared.

Another recent archaic mammal, the lemur (Fig. 373), again a relic of the past, represents the mammalian stock that gave rise to the Primates. It has a fox-like face but its general anatomy fore-shadowed a monkey.

The Old World monkeys represent a stock from which the monkeys, apes and man descended. The muzzle start shortening, eyes fully look forward and the entire body fore-shadows man.

The Anthropoid apes like gibbon, chimpanzee, urangutan and gorilla are almost human. The Australian bushman is a relic of an early human race.

Each of these stages marked changes that led to the erect posture of man. The earliest forms lived in water and swam by undulating movements of their body, using the fins as rudders and balancers. The swamp-dwelling, air breathing fishes modified the fins into paddles and finally into limbs. Then they crawled out of the swamps. They learned to raise the belly (Fig. 492) off the ground and to run about in search of food or to escape enemies. Next they began to crawl up tree stems and became expert climbers. Some of them gripped the branches

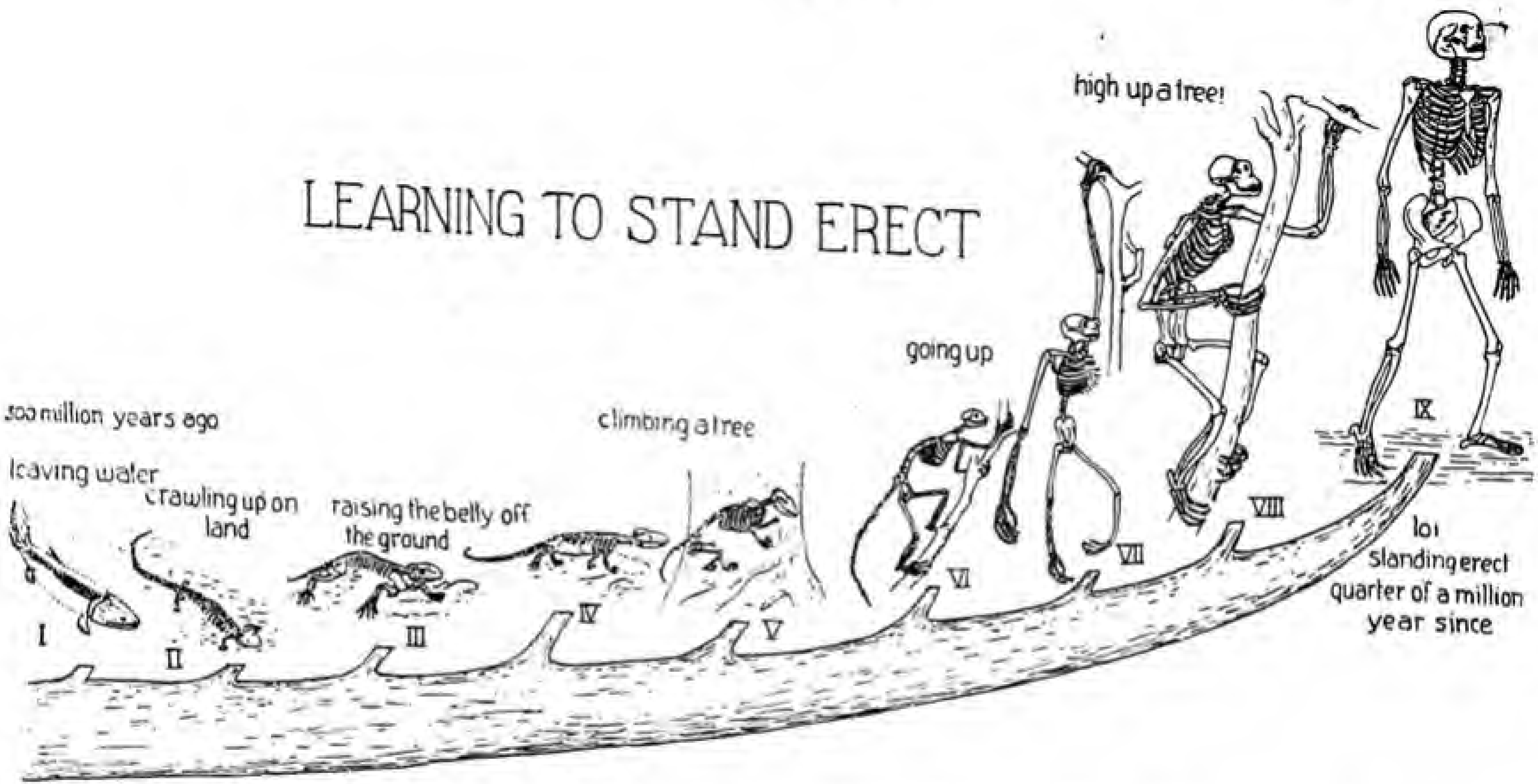


FIG. 492. Man is but a modified fish—a fish that left water and began to breathe air 300 million years ago, learnt to crawl, climbed trees, then came down and stood erect on the ground hardly a quarter of a million year ago. He is no more a picture of God than the fish whose lineal descendent he is. Human evolution is merely a story of a fish learning to stand erect on two legs on the ground. His 'swollen head' is the head of the fish and his hands and legs the fins. I. *Eusthenopteron*, Devonian lobefinned fish. II. *Eogyrinus*, Carboniferous amphibian. III. *Seymouria*, Permo-carboniferous reptile. IV. *Cynognathus*, Triassic Promammal. V. Opossum, primitive mammal. VI. *Notharctus*, Eocene lemuroid Primate. VII. Typical anthropoid gibbon. VIII. Chimpanzee an anthropod. IX. Man. (*Modified from Gregory, courtesy of the American Museum of Natural History*).

and began to swing from (Fig. 438) one branch to another. A few of these tree-swingers jumped down on the ground and began to run semi-erect. Stones were picked up and used in defence and offence: Man was born.

Man thus emerged from an arboreal stock The arboreal ancestry has given him many boons. His hand, binocular vision of eyes, protrusive lips free from the gum (which help articulation of words), enlarged brain, powers of judgement, capacity to turn the head from side to side, locating sounds and so on. On leaving the tree, the hand was emancipated from the task of grasping, but was free to pick up things, bring them near the eyes for close inspection and convey food to the mouth. The snout was thus relieved of picking up food and began to recede.

Man is in short a modified fish He inherits from the fish his whole anatomy : the backbone, the skull, the jaws, the teeth, the eyes, the nose, the ear, the girdles, the limbs and even his brain. His jaws are one of the modified gill arches, his teeth modified placoid scales and his hands and feet the modified fins. The articulated speech that characterizes him is produced by larynx, which is a highly specialized modification of the gill arches. His brain, that now probes into the mysteries of the universe "began as a simple automatic mechanism for directing his motor and digestive apparatus towards his next meal".

Morphology of the human body testifies to his fish ancestry. His embryonic development repeats and reiterates his descent from the fish. The early human embryo (Fig. 484) is indistinguishable from the fish embryo. It has a yolk sac, though the human egg has no yolk. It has gill-slits, aortic arches, two-chambered heart, paddle-shaped limb-buds and segmental muscles. It has a swimming pool for its special use in the amniotic sac, in which it can float before coming on land.

The evidence of fossil is however very incomplete : there are numerous gaps. Undoubtedly the primates arose during the Eocene but the separation of the Hominid branch from that of the apes took place during the middle Tertiary. Between this and the appearance of various fossil men (Chapter XXIV) during the Pleistocene there is a blank.

There is however no doubt that man evolved from fish-like ancestors like all other vertebrates He is very much a product of organic evolution and not of special creation.

"Gott schuf den Menschen nach seinem Bilde, dass heisst vermutlich, der Mensch schuf Gott nach dem seinigen". - *George Christoph Lichtenberg.*

God did not create him in His own shape but he created various gods in his own shape and endowed them with all his vices and virtues.


OUR FACE FROM FISH TO MAN
TASMANIAN
Mani.

FIG. 493. Our face from fish to man. A comparative series of extinct and living forms, though not all on the direct line, to show the evolution of the much admired human face through 540 million years. To begin with, the face was merely a terrible fish-trap, set with sharp teeth, and designed to secure the daily food. The mouth, which is the gateway to the stomach, dominates the face : thus in the Palaeozoic shark the face was merely a bony mask, pierced by the large mouth and by small holes for the eyes and nostrils. The face was "all mouth". The eyes appear on the sides of the head, but gradually shift forwards, until in the Anthropoid Apes for the first time they can be focussed on objects held in hand. The nostrils are wide apart at first but come together into a true nose in the apes. The face has undergone great changes in adaptation successively to different kinds of life, until man is at once recognized by his "swollen head" and human expression. Man's face in the shape of which he created god again and again, is simoly moulded upon an organ which was meant to direct the mouth to the next meal. His voice, which he sends over the radio, is a vestige of the gill apparatus of an ancient shark, put to a new use. His delicate teeth, the scales of the skin of the Palaeozoic shark. 1. *Cladoselache*—Face "all mouth" 350 million years 2. *Eusthenopteron*—Devonian air-breathing fish. 300 million years 3. *Eogyrinus*—Carboniferous Batrachian. 223 million years. 4. *Seymouria*—Permo-Carboniferous Reptile. 220 million years 5. *Ictidopsis*—Triassic mammal-like Reptile. 180 million years 6. *Eodelphis*—Cretaceous Reptile-like mammal. 100 million years. 7. *Propithecus*—Common ancestor of man and ape. 60 million years. 8. *Recent*—Old World monkey represents common ancestor. 40 million years. 9. Chimpanzee—Represents an extinct prehuman stock. 10. Tasmanian—Represents Pleistocene man. 2 millon years. 11. Roman athlete—*Homo sapiens*—mouth still centre, but face "index of mind". (*Original photograph of a wall case in the Zoology Museum, St. John's College, Agra*).

Evolutionary changes are continuous. They are even now going on. In the course of evolution millions of animals have become extinct by over specialization, race senescence and other causes. What is the future of man ? In the immediate future—5-10 million years hence perhaps—he will

FIG. 494. Ants belong to a class that is best fitted by organization and habit for life on earth. All forms of animal life appear almost to be Nature's unsuccessful experiments at discovering the one and only successful form of life : the ants. They have a social system more perfect than the human society. They have a government based on all that man has ever struggled for but never achieved. Man lives for himself : ants live, love and labour for their race. Brains they have but do not, like man, suffer from a "swollen head". Given time, they will oust out every competitor from this planet. They alone have the chance of taking the place of man when the human race becomes extinct by natural processes.

be a toothless, hairless, nailless refined being. His little toes, vermiform appendix, eyebrows, eyelashes, ear pinna and other vestigial organs will have disappeared. His bald head will continue to become more and

more *swollen* to accommodate an ever increasing brain. He will merely be an over-specialized brain with just enough of body to maintain it. If supper-annuation and race senescence are too slow, the monstrous development of his brain at the cost of the body, will guarantee his extinction. Luck favouring, thirty or forty million years hence, museums (supposing they exist then) may exhibit complete fossil skeletons and perhaps even restorations of the curious animal that was all *swollen head* and no body and hence became extinct soon after its appearance. Who shall inherit the Earth from us when we 'fade out'?

> 'Die Welt wird alt und wird wieder jung
> Doch der Mensch hofft immer Verbesserung''. *Schiller*

Some Misconceptions

There are numerous popular misconceptions about the doctrine of organic evolution :

1. *Evolution attempts to explain the origin of life.* This is a very common erroneous impression The doctrine of evolution does nothing of the kind. On the contrary, it merely tries to explain how life has come to manifest itself in the myriad forms that we find today It does not concern itself with what is life or how life arose.

2. *Evolution and Darwinism are synonymous.* There is nothing more erroneous than this statement. Darwinism is only *one* of the several attempted explanations of the mechanism that brings about evolution.

3. *You cannot see evolution* While it is true that evolution cannot be readily observed, the process has been experimentally reproduced and imitated in breeding of domestic animals. It is not possible to see evolution taking place in Nature because evolution is a process that requires hundreds of millions of years but man hardly lives for 50 years. You cannot see the hour hand of a clock moving if, for example, you lived only for five seconds. From other evidence, however, you can become conscious that the hour hand does move and can also form an idea of the mechanism that brings about this movement.

4. *Evolution occurred in the past.* This idea is entirely wrong. Evolution has never come to a standstill. The changes that took place in the past have caused the changes that are now taking place and these in turn will give rise to changes in the future and so on endlessly.

5. Many people, who are willing to *admit that evolution occurs in animals, refuse to concede that man is also subject to it.* Indeed some bigoted people are still unwilling to consider that man is also an animal. Instead of

recognizing our brotherhood with the amoeba, fish, frog, bird, monkey and other animals, these people arrogate man alone to a divine origin. Such an idea is not only wholly absurd but also demonstrates the swollen-headedness of man. The same laws of life, inheritance and evolution that govern other animals govern man also. Man is as much an animal as the amoeba or the frog. He is a product of past evolution and is equally subject to future evolutionary changes.

6. *Man came from the monkey.* This silly statement that one often hears is credited to poor Darwin. Darwin never advanced any such theory. No biologist has ever considered the monkey as an ancestor of man. The monkey and man are both the result of the past evolution and one cannot thus give rise to the other. Both are descendants of a common stock and are evolving each in its own line.

7. Many who admit evolution of man often assert that *evolution will lead man to divinity in course of time. A superman will descend from man.* While this is plausible, it is not necessary. Whether man is evolving into superman or not it is not definite, but it is within the laws of the game of evolution for man to become extinct. The same laws that brought him into being will ensure his disappearance in due time.

RESUMÉ

I. Variations

1. Variation includes differences in structure, physiology and habit. Continuous variations are graded. Discontinuous variations are mutations that arise all on a sudden and in which the extremes are not connected by intermediate stages.

II. Heredity

2. Heredity is passage of characters from parent to offspring.

3. Mendelism involves the laws of inheritance and includes : i. law of paired units, ii. law of dominance, iii. law of independent assortment and iv. law of segregation

4. In a monohybrid a pair of characters enter into a cross. In the offspring the characters do not blend but one dominates and other remains unexpressed. In the next generation the characters segregate and the dominant and recessive characters reappear in the ratio 3 : 1. One of the three dominants and the single recessive are homozygous ; the remaining two dominants are heterozygous and segregate in the next generation in the same ratio.

5. When more than one pair of characters enter a cross, each is inherited independently of the other.

6. In many animals sex is a Mendelian character, the genes of which are located in the sex chromosomes. In some animals the female is homozygous and male heterozygous, while in others the converse is true.

7. Linkage is inheritance of several characters together, because their genes are located in the same chromosome.

III Organic evolution

8. Organic evolution is descent with modification. Evidence for evolution is derived from i. classification, ii. connecting links, iii. comparative morphology, iv. vestigial organs, v. embryology, vi. atavism, vii. palaeontology, viii. missing links, ix. zoogeography, x. changes under domestication, xi mutations and xii. physiology and experiment.

9. The theories of evolution include Lamarckism, Darwinism and mutation theory.

10. Lamarckism states that environmental changes by creating new needs, induce new habits in animals. This results in use and disuse of organs. Use increases and develops an organ but disuse leads to its atrophy and disappearance. Structural modifications thus result. The changed habits and with them the structural modifications are inherited.

11. Darwinism is based on small inheritable variations that are useful in the struggle for existence. These are conserved and the useless variations are eliminated, leading to a sort of natural selection. Such variations do not actually exist and therefore natural selection is a myth.

12. The mutation theory is a modification of Darwinism. Sudden, large and inheritable variations—mutations—that are useful are preserved by natural selection. Not only mutations are too rare to account for evolution, but they also represent germ-weakening (race senescence). They are thus unfits that have no survival value.

13. Inheritance of modification of habit is the cause of evolution. The much misunderstood Lamarckism alone thus accounts for evolution, but not Darwinism.

IV. Human evolution

14. Man was not created by a special act of God but he is a product of evolution.

15. He is descended from fish-like ancestors through a long series of modifications that enabled them first to crawl on land, climb trees and then stand erect on hind limbs on the ground.

16. As evolutionary changes are still in progress, man will become extinct at no distant period and may give place to other forms of animals.

GLOSSARY

This Glossary is neither a complete dictionary of zoological terms nor of such terms used in the book. For definitions of the terms not included in this Glossary the student should seek the help of the Index to locate them in the text.

A

Abdomen. The posterior part of the trunk.

Abductor. A muscle that draws a part away from the body axis or separates two parts.

Abiogenesis. Spontaneous generation.

Aboral. Opposite the mouth.

Absorption. The selective taking up of substances in solution.

Acclimatize. Become habituated to an environment, not native to the animal.

Accommodation. Adjustment of the eye for distinct vision at different distances.

Acetabulum. The concave surface of pelvis that receives the head of femur.

Acinus. Small terminal sac in lung or gland.

Acquired character. A character that originates due to the environment, during the life of the individual.

Adaptation. The structural or functional fitness for a particular environment. The process of becoming so fitted.

Adductor. A muscle that draws a part towards the body axis or draws the parts together. Antagnist of abductor.

Adipose. Fatty.

Adjustor neuron. A neuron in a nerve centre that passes an impulse from the receptor to the effector neuron in a reflex act.

Adrenal. A ductless gland, often also called suprarenal gland, near the kidney. It secretes the hormone adrenalin.

Adsorption. Adhesion of an extremely thin layer of molecules of a substance to the surface of a solid.

Aestivation. Passing the summer in a torpid state.

Afferent. A blood vessel or nerve that leads away from a given part.

Agglutination. Clumping together as of blood corpuscles.

Albinism. The absence of natural pigment in skin, hair or feather.

Alimentary. Pertaining to food, digestion and digestive tract.

Allantois. One of the embryonic membranes. An outgrowth of the hind gut of the embryo that serves as embryonic organ of respiration and excretion in reptiles and birds. Extends and unites with chorion to form the foetal placenta in mammals.

Allele. Allelomorph. Alternate Mendelian characters like black and white colour of coat: Pair of genes located at the same place in homologous chromosomes and that give rise to contrasting characters in the offspring.

Alternation of Generation. Metagenesis.

Altricial. Birds that hatch naked and blind.

Alveolus. The socket for a tooth. Terminal air sac of lung.

Ambulacral. Pertaining to the rows of openings through which the tube feet of Echinodermata are extruded.

Amino acid. Organic acid containing NH_2-radical: the unit that builds proteins.

Amitosis. Direct division of nucleus without the formation of the spindle and asters.

Amnion One of the embryonic membranes formed out of the extraembryonal area of the blastoderm in reptile, bird and mammal. It is the innermost membrane that encloses the embryo and is filled with the amniotic fluid.

Amoebocyte. Colourless corpuscles of the blood capable of pseudopodial locomotion.

Amoeboid. Putting out pseudopodia like an amoeba.

Amphibious Living both in water and on land.

Amphicoelous A vertebra with the centrum concave at both ends.

Amylase. A pancreatic enzyme that changes starch into sugar.

Ampulla Bladder-like enlargement.

Anabolism. The building-up stage of metabolism: digestion, assimilation, growth, etc.

Anaerobe. Animal not requiring free oxygen for respiration

Analogy. Similarity of form and function but of different origin. Example: Wing of bird and butterfly.

Anamnia. Vertebrates like Cyclostomata, Fishes and Amphibia that lack an amnion.

Anaphase The phase in cell division when the chromosomes migrate from the equator of the spindle to the poles.

Anastomosis. Union of blood vessels or tracheae.

Antenna. An appendage on the head of an arthropod used as a sensory organ (not of sight).

Anterior. Forward. Front or head end Opposite of posterior.

Antigen. A substance that stimulates the formation of an antibody in an animal.

Antitoxin. A substance in the blood that neutralizes a toxin.

Anus. Posterior opening of the alimentary canal

Aorta A large artery that arises from the heart

Aortic arch Paired large arteries from the ventral aorta in the pharyngeal region.

Arboreal. Living on trees.

Aristotle's lantern. The masticatory apparatus of sea urchin.

Archenteron The primitive gut formed by gastrulation in an embryo.

Artery A vessel that carries blood away from heart.

Asexual. Not related to sex Reproduction without fusion of gametes.

Assimilation Incorporation of the digested and absorbed food into the living protoplasm.

Asymmetry. Absence of symmetry

Atriopore The external opening of the atrial chamber in the Protochordata.

Atrium [illegible] cavity such as the auricle of heart.

Auditory. Pertaining to the organ of hearing.

Auricle. The receiving chamber of the heart.

Autonomic. The part of nervous system that functions independently of the brain.

Autotomy Voluntary breaking off of a part by an animal. Example: lizard breaking off its tail.

Axial skeleton. The skeleton that lies in the axis of the body: skull, vertebrae, sternum and ribs.

Axolotl. The salamander larva that has acquired sexual maturity without metamorphosing into the adult.

Axon. The process of a neuron that conducts impulses outwards.

B

Back-cross. Mating between a heterozygote and a homozygote.

Basement membrane. A thin connective tissue membrane to which an epithelium is attached.

Behaviour. The sum-total of an animal's movements in response to environmental stimuli

Benthos. The life of the deep-sea bottom.

Bevölkerung. Population.

Bilateral symmetry. Symmetry such that the body can be divided by one median plane into equivalent right and left halves, each a mirror image of the other.

Bile. The secretion of the liver in vertebrates that is in the nature of an excretion; aids digestion and serves various other functions.

Binary fission. Division of an animal into two similar animals.

Binomial. Name of an animal consisting of two parts; a generic and a specific.

Biocönesis. The organisms that inhabit a given habitat. Lebensgemeinschaft.

Biogenetic law. In the embryonic development of animals there appear stages that were present in the adults of ancestral forms.

Biotope. Standort. Station. The place in which animals live. Habitat.

Biparental. Involving two parents.

Biramous. An appendage in which the telopodite consists of two branches—endopodite and exopodite—as in crustacea.

Bladder. Membranous bag containing air or liquid *e. g.* gall bladder, urinary bladder of frog and air bladder of fish.

Blastocoel. The cavity of blastula.

Blastoderm. The layer of cells that forms the blastula.

Blastodisc. The germinal area on the egg, rich in yolk, that gives rise to the embryo.

Blastomere. One of the early cells formed by segmentation of the zygote. One of the cells of the blastoderm.

Blastopore. The opening into the archenteron in a gastrula.

Blastula. An early stage of embryo. Usually a hollow sphere of cells.

Blepharoplast. A granule in a cell that gives rise to flagellum or cilium.

Blood. A liquid tissue that circulates in the vascular system and serves as a medium of transport of material.

Brachial. Pertaining to the arm.

Branchial. Pertaining to gill.

Bronchus. A large division of the trachea conveying air to the lungs.

Brutfürsorge. Parental care involving precautionery measures for the safety of the offspring.

Brutpflege. Parental care involving direct guarding, tending and nursing of the young.

Buccal. Pertaining to the mouth.

Bud. Part of an animal that grows out and gives rise to a new individual.

Bursa. Pouch or sac.

Byssus. Tough threads that attach mussels to solid objects.

C

Caecum. (Pl. Caeca). Pouch-like extension of the digestive tract closed at one end.

Canaliculus. The small canal that connects the lacunae and the Haversian canal in a bone.

Capillary. A minute tube with unicellular wall, through which diffusion takes place. Forms a network between arteries and veins.

Carapace. A hard, dorsal shield covering body as in crayfish or tortoise.

Cardiac. Belonging to the heart.

Carnivorous. Feeding on flesh or on other animals.

Carpus. Wrist.

Castration. Removal or destruction of the gonads, especially the testes.

Catabolism. Destructive metabolism. The breaking down of complex substances in protoplasm.

Caudal. Pertaining to the tail. Referring to the posterior end of the body.

Caverniculous. Inhabiting caves.

Cell. Structural and functional unit of body. A bit of protoplasm with a nucleus.

Central nervous system. The part of nervous system that receives afferent impulses and sends out efferent ones and comprises paired or chain of ganglia or brain and spinal cord.

Centriole. Centrosome. A granule in the centre of the aster during mitosis.

Centrolecithal. An ovum with the yolk massed in the centre.

Centrosome. A clear mass near the nucleus surrounding the centrioles in a cell.

Centrum. The body of vertebra.

Cephalic. Pertaining to head. Referring to the anterior region.

Cephalothorax. Division of body with the head and thorax combined.

Cercaria. A trematode larva.

Cerebellum. Ant[illegible] part of the hind brain.

Cerebrum. [illegible] part of fore brain.

Cervical. [illegible]

Chelicera. [illegible] anterior appendages of an Arachnid.

Chitin. A non-prot[illegible] material that is secreted in the exoskeleton of arthropods.

Choanocyte. [illegible] and flagellated cells lining the canals of sponges.

Chondrin. [illegible] cartilage.

Chondrocranium. [illegible] cranium of elasmobranch fish and of the embryos [illegible]

Chordata. [illegible] notochord at some time during life.

Chorion. [illegible] of the egg of a terrestrial vertebrate or of [illegible]

Choroid. [illegible] vascular coat of eye of a vertebrate.

Chromatin. [illegible] in the nucleus of a cell.

Chromatophore. [illegible]

Chromosome. [illegible] chromatin in the nucleus. Bear the genes [illegible]

Chyl. [illegible] absorbed in the intestine by the lymphatic vessels.

Chyme. [illegible] from the stomach into the duodenum.

Cilium. [illegible] processes of a cell.

Cirrus. [illegible] flexible appendage.

Cleavage. The [illegible] of the egg [illegible] and the resulting early blastomeres.

Clima. The sum [illegible] of the atmospheric and geographical factors that make the life and [illegible] possible.

Climax community. [illegible] of animals that have become permanently established in an area.

Cloaca. Common passage into which end the digestive tract, excretory and reproductive ducts.

Cnidoblast. A cell of a Coelenterate that develops a nematocyst.

Coccyx. The vestigial caudal portion of the vertebral column in man and apes.

Cocoon. Protective case of silk or other material for egg, larva, pupa or adult.

Coelom. Body cavity formed by the splitting of the mesoderm and lined by peritoneum.

Colony. Group of individuals of the same species that live attached together.

Commesalism. Association of different species, by which one is benefited and others not harmed.

Commissure. Nerve fibres that connect nerve centres on either side of the median line.

Community. A group of animals that live together and are related by environment.

Conditioned reflex. A habitual response different from that elicited by an original stimulus.

Conjugation. Temporary union of two Protozoa for exchange of material in reproduction.

Connective. Nerve fibres that connect centres on the same side of the body.

Contractile vacuole. A liquid-filled space in a Protozoa that alternately fills and empties.

Convergence. Resemblance of unrelated animals because of similar habits of life.

Coordination. The integration of activities.

Copulation. Sexual union for the passage of the sperm from the male into the female.

Corium. Dermis beneath the epidermis of the skin.

Cornea. The outer transparent coat of the eye.

Corpus luteum. The cells that replace the discharged follicles in the ovary of mammals and that have an endocrine function.

Coupling. The association together in linkage of the two dominant or of the two recessive characters determined by different pairs of genes

Cranial. Pertaining to the brain.

Cretin. Mentally and physically deficient due to lack of the thyroid hormone.

Crop. Thin-walled expansion of the digestive tract for storage of food.

Crossing over. Transfer of genes from one chromosome to another during synapsis.

Ctenidium. (Pl. ctenidia) The gill of Mollusca.

Cutaneous. Pertaining to the skin.

Cuticle. Non-cellular external covering.

Cyst. Resistant protective covering round a cell or a Protozoan during unfavourable weather or during reproduction.

Cysticercus. A tapeworm larva consisting of an inverted scolex in a sac.

Cytoplasm. Part of cell outside the nucleus but within the cell wall.

Cytostome. Cell mouth.

D

Degeneration. Simplification of structure and loss of function.

Dendrite. Process of a neuron that conducts impulses to the cell body.

Deuteroplasm. Yolk of the ovum as distinct from nucleus and cytoplasm.

Dentine. The hard part of tooth underneath the enamel.

Dermis. Deeper part of the skin.

Dextral. Referring to a Gastropod molluscan shell spirally coiled to the right.

Diaphragm Muscular partition between thoracic and abdominal cavities in mammals.

Diencephalon. The second part of the brain of vertebrates comprising the optic tracts, thalami, pineal and pitutary. Thalamencephalon.

Digestion The process by which food is rendered fit for absorbtion and assimilation.

Digitigrade. Walking on the toes.

Dihybrid. The offspring of parents differing in two characters.

Dimorphism. The existence of an animal in two forms.

Dioecious. With the male and female reproductive organs in separate individuals

Diploblastic With two germinal layers : ectoderm and endoderm.

Diploid. Somatic number of chromosomes double that of the mature germ cell.

Discoidal cleavage. The cleavage in a polar differentiated telolecithal ovum in which the blastomeres form a disc at the animal pole.

Distal. Away from the point of origin.

Diurnal. Pertaining to the day time.

Divergence. Appearance of different characters in related animals under different conditions.

Domestication. The taming of wild animals by man, with consequent changes in their environment and habit.

Dominant character. A character inherited from one parent that manifests itself to the exclusion of a contrasted character from another parent.

Dorsal. Referring to the back surface.

Duct. A tube for the passage of a liquid or other metabolic product.

Ductless gland. A gland that manufactures an endocrine secretion or hormone and pours it directly into the blood.

Duodenum. The first part of the intestine of vertebrates.

E

Ecdysis. Moulting. Shedding of the cuticle in an Arthropod and of the scales in snakes and lizards.

Ecological valence. The amplitude of the factors influencing life, within which lies the capacity of an organism to exist.

Ecology. Study of animals in their inter-relation to their environment.

Ectoderm. The outer germinal layer of an embryo.

Ectoparasite. A parasite that lives externally on the host.

Ectoplasm. The superficial part of the cytoplasm in Protozoa.

Efferent. A blood vessel or nerve that leads away from a part.

Effector. A structure that transforms motor impulses into motor action.

Egest. To discharge undigested and unabsorbed food from the alimentary canal.

Embryo. A young animal before hatching or before birth.

Embryonic membranes. Cellular membranes like amnion, chorion, yolk sac and allantois that envelope the embryo and subserve its metabolism.

Emulsion A mixture of two liquids in which one is in a state of minute droplets suspended in the other.

Enamel. The dense white covering of scales of cartilagenous fish and of teeth.

Encyst. To become enclosed in a cyst.

Encystment. The formation of a hard resisting covering about an animal.

Endocrine. Ductless gland. Also secretions of such.

Endoderm. The inner germinal layer of cells that line the archenteron in the early embryo. Appears in the gastrula stage.

Endomixis. Reorganization of the nuclear material in protozoa.

Endoparasite. A parasite that lives within the host.

Endoplasm. The deeper portion of the cytoplasm in Protozoa.

Endoskeleton. Internal supporting framework of the body.

Endostyle. A ciliated groove on the ventral wall of pharynx in sea squirts and amphioxus that is the homologue of the thyroid gland.

Enteron. Digestive cavity, especially the part that is lined by endoderm.

Environment. The sumtotal of the external conditions that surround an organism.

Enzyme. A ferment or catalyst produced by living cells that in minute quantities bring about specific chemical transformation but that is not itself used up in the process.

Epiboly. Growth of fold of blastoderm over the embryo forming an archenteron in between.

Epidermis. A layer of cells that cover the external surface.

Epididymus. The efferent tubules of testes.

Epiglottis. The cartilagenous piece that guards the glottis opening and prevents the food from entering it when swallowing.

Epiphysis The end of a bone that ossifies separately. Dorsal outgrowth of the diencephalon of the brain of vertebrates—the pineal body.

Epithelium. A layer of cells that lines a surface or a cavity.

Epizoic. Living upon the surface of another animal as opposed to the entozoic.

Erepsin. Protein-splitting enzyme produced in the intestine.

Erythrocyte. Red blood cell or red corpuscle of the vertebrate blood.

Eugenics. Improvement of the human race by improved sexual relations based on laws of heredity.

Eustachian tube. The tubular passage that connects the pharynx and the middle ear in terrestrial vertebrates.

Evagination. An outpocketing from a hollow structure.

Evolution. Descent with modification. The process of progressive increase in complexity of structure and function that results in the formation of complex forms from simpler ones.

Excretion. Waste products of metabolism. The process of elimination of metabolic wastes.

Exoskeleton. The external supporting covering.

Eye spot. Pigment-containing mass of cells capable of perceiving light but incapable of vision.

F

F_1, F_2, etc. Abbreviations for first filial, second filial, etc., indicating the successive generations that follow a crossbreeding.

Faeces Excrement. Undigested residues of the food expelled from the digestive tract.

Fallopian tube. The oviduct of mammals.

Fauna. The animal life of a region or time.

Fertilization The union of sperm and ovum, especially their nuclei, that initiates embryonic development.

Fibrin. The fibrous part of the blood clot.

Fin. An extension of the body of an aquatic animal used in locomotion.

Fission. Division into two or more parts in assexual reproduction.

Flagellum. A threadlike vibrating process.

Flame cell. Terminal excretory cell of certain invertebrates that contains beating cilia, giving a flickering appearance.

Foetus. The later stage of an embryo that develops within the uterus.

Food. Substance that provides building material and energy for an animal.

Food vacuole. An intracellular digestive organelle. A space in a cell filled with food particles.

Foramen. (Pl. Foramina). A perforation through a bone or a membrane.

Fossil. Relic of organisms that existed in the geological age other than the present.

Fossorial Adapted for digging.

Function. Activity of an organ or an animal.

G

Gamete. Mature reproductive cell, either female or male.

Gametogenesis. Maturation of the primordial germ cells by reduction division. Formation of the gametes by reduction division.

Ganglion. (Pl. Ganglia). A group of nerve cell-bodies acting as centre of nerve function.

Gastrovascular. Serving both digestive and circulatory functions.

Gastrula. An embryo with the primary digestive tract or archenteron. An inverted blastula with ectoderm and endoderm.

Gemmation. Reproduction by budding as in Hydra.

Gemmule. An internal bud of a fresh-water sponge, enclosed in a cyst and capable of tiding over unfavourable conditions.

Genes. Factors or hereditary determiners. Units of inheritance.

Genital. Referring to reproductive organs and function.

Genotype. The genetic constitution without reference to its external appearance.

Germ Cell. Reproductive cell.

Germinal variations. Variations due to germ cells.

Germ layer. One of the primary membranes (two or three) of an embryo, out of which all the organs develop : ecto-, meso and endoderm.

Germ plasm. Gametes and the cells and tissues taken together.

Gestation. The period of carrying the foetus within the uterus.

Gill. Organ for aquatic respiration.

Gill slits. The paired openings that appear in the pharynx during development of Chordates and along the sides of which gills develop in the aquatic Chordates.

Gizzard. Heavily muscularized part of the alimentary canal

Gland. An organ of secretion or excretion.

Glochidium. The larva of a fresh-water mussel.

Glomerulus. A knot of blood capillaries in a renal capsule of the kidney.

Glottis. The slit-like opening of the pharynx into the larynx.

Glycogen A polysacharid carbohydrate stored in the liver and muscles. Animal starch.

Gonad Reproductive organ : ovary or testis.

Gregarious. Habitually living in herds, flocks or groups.

Gustatory. Relating to the sense of taste.

Gynandromorph. An individual of a dioecious animal, male in one part and female in another part of the body.

H

Habit. A form of behaviour of animal acquired as a result of repeated action.

Habitat. The natural dwelling place of an animal.

Hæmal. Referring to blood and blood-vascular system.

Hæmocoel Reduced coelom that also functions as part of the blood-vascular system.

Hæmoglobin. The red colouring matter --a compound of protein and iron--found in blood and capable of combining with oxygen and again readily parting with it.

Hæmolysis. Dissolution of the erythrocytes.

Halteres. The knob-like balancers in Diptera that represent the vestigial hind wings.

Haploid. Halved chromosomes as in the gametes.

Haversian canal The canal in a bone that contains blood vessels.

Head The anterior part of the body containing the mouth, the dominant parts of the nervous system and the chief organs of special sense.

Hepatic portal system. Veins that leave the digestive tract first to enter the liver sinusoids in a vertebrate.

Herbivorus Feeding chiefly on vegetable matter. Also called phytophagous.

Heredity. Transmission of characters from parent to offspring.

Hermaphrodite. An animal with both female and male reproductive organs in the same individual.

Heterozygote. An individual that results by the union of germ cells with unlike genes for a character.

Hibernate. Passing winter in a torpid state.

Holoblastic. Total segmentation of ovum.

Holophytic nutrition. Photosynthetic mode of nutrition.

Holozoic nutrition. Nutrition typical of animals, requiring complex organic compounds.

Homology. Structural similarity due to common origin

Homozygote An individual that results by the union of germ cells with like genes for a character.

Hormone. A secretion of an endocrine gland that serves as a chemical regulator or coordinator.

Host. The animal that harbours another as a parasite.

Hybrid. A heterozygote. An offspring of two parents that differ in one or more inheritable characters.

Hypermetamorphosis. Metamorphosis in insects involving more than one kind of larval stage.

Hyperparasite. A parasite on another parasite.

Hypertrophy. Abnormal increase in size of a part.

I

Ileum. The last part of the small intestine in vertebrates.

Ilium. The dorsal bone of the pelvis.

Imago Adult of insects.

Immunity. Absence of susceptibility to a disease or a parasite.

Inbreed. To mate related animals.

Incus. The anvil bone of the auditory ossicles in the middle ear.

Ingest. To take food into the digestive tract.

Inheritance. The sumtotal of characters transmitted from parent to offspring.

Instar. The period between ecdyses in insects.

Instinct. An inherited action or habit that is invoked by certain stimuli.

Insulin. The harmone produced in the islets in pancreas and regulating sugar metabolism.

Intelligence. Action modified by previous experience. Ability to learn by previous experience.

Intercellular. In between the cells.

Intestine. The part of the alimentary canal between the stomach and anus.

Intracellular. Within the cell.

Invagination. Folding-in or tucking in to produce a cavity.

Invertebrate. Non-Chordates and Chordates that lack a vertebral column.

Irritability. The ability to respond to external stimuli. One of the unique characters of life.

Isolecithal. An egg in which the yolk is not abundant and nearly uniformly distributed throughout.

J

Jejunum. The second part of the small intestine of mammal.

Joint. Place of union of two bones or other hard plates.

K

Karyokinesis. Mitosis.

Karyosome. Nucleolus composed of chromatin.

Keratin. Nitrogenous constituent of horn, nail, hair, feather and scales.

Kidney. Organ of excretion and elimination in vertebrates.

L

Labium. The posterior boundary of mouth—lower lip.

Labrum. The anterior boundary of mouth—upper lip.

Labial. Pertaining to lip.

Lachrýmal. Pertaining to tears.

Lacteal. Lymphatic vessel from the small intestine. Pertaining to milk.

Larva. The early and usually the active feeding stage that comes after the embroy and that is unlike the adult.

Larynx. The enlarged anterior part of trachea in vertebrates that contains the vocal cords.

Lebensgemeinschaft. Biocönesis.

Lebensraum. Biosphere. The total space of the earth filled up by living beings.

Leptotene. An early stage in the prophase of meiosis in which the chromosomes first appear as long thin threads.

Leucocytes. Colourless blood corpuscle.

Ligament. Fibrous connective tissue that binds structures other than muscles.

Lingual. Pertaining to the tongue.

Linin. The reticulum in the nucleus that contains the chromatin granules.

Linkage. Inheritance of characters in groups, because of their genes being located in the same chromosomes.

Lipase. Enzyme that splits fats.

Lumen Cavity of an organ.

Lymph. Colourless fluid that occurs in lymph vessels and in among the tissues.

M

Macrogamete. Egg cell. Female sex cell.

Macronucleus. The larger of the two nuclei of Ciliata that is concerned with vegetative functions.

Madreporite. A sieve-like plate leading to the water vasculer system of Echinodermata.

Malleus. One of the auditory ossicles: modified quadrate.

Mandible. The lower jaw of a vertebrate. Jaw of an Arthropod.

Mantle. A fold of the dorsal part of the body wall of Mollusca that secretes the shell.

Marine. Animals that inhabit sea, ocean or other salt waters.

Marsupium. External pouch in the Metatheria for carrying the young.

Matrix. Intercellular substance in cartilage and bone.

Maturation. The changes in the germ cells that make them fit for fertilization, comprising reduction, division and throwing off of the polar bodies; segregation of homologous chromosomes so that each gamete contains half the usual number of chromosomes.

Maxilla. The upper jaw of vertebrates. Gnathal appendages behind the mandible in the Arthropods.

Medulla oblongata. Posterior part of brain.

Medullated nerve. Nerve fibre that possesses a fatty sheath.

Medusa. Jellyfish, a free-swimming sexual individual of Coelenterata.

Meiosis. Same as maturation.

Memory. Persistence of some modification in a nerve cell resulting from its activity.

Meninges. Membranous covering of the brain and spinal cord.

Meroblastic Incomplete cleavage of zygote, especially that is rich in yolk.

Mesencephalon. The midbrain of vertebrates.

Mesenchyme. Mass of mesodermal cells that give rise to the connective tissues generally.

Mesentery. The tissue that suspends organs in the body cavity and is continuous with peritoneum.

Mesoderm. The middle germinal layer formed between the ectoderm and endoderm.

Mesogloea. The gelatinous material between ectoderm and endoderm in diploblastic animals like the jellyfishes

Mesonephros. The kidney of lower Chordates and Vertebrates.

Metabolism. The sumtotal of the vital activities of constructive and destructive changes in an animal.

Metagenesis Alternation of sexual and asexual generations in the life-cycle of an animal.

Metamere. One of the series of homologous parts of an animal as in the Annelid or Arthropod.

Metamerism. Segmental repetition of homologous parts.

Metamorphosis. The series of changes of form as from larva to adult after the embryonic development.

Metanephros. The kidney of higher vertebrates

Metaphase The phase in mitosis characterized by the splitting of the chromosomes aligned on the equator of the spindle.

Metazoa. Multicellular animals in which the cells are arranged in tissues.

Metencephalon The fourth region of the brain comprising the cerebellum and pons.

Microgamete. Male sex cell or sperm cell.

Micron (Pl. Micra). Unit of microscopic measurement. One-thousandth of a millimetre, represented by the Greek letter μ

Micronucleus. The smaller of the two nuclei in Ciliata that is chiefly concerned with reproduction.

Micropyle. The minute opening in the egg for the entry of sperm.

Mimicry. Resemblance of a harmless and otherwise defenceless animal to another harmful or otherwise protected animal.

Miracidium. The first larva of flukes.

Mitosis. Indirect cell division preceded by the appearance of fibrous spindle, a definite number of chromosomes that split longitudinally to give rise to two equal sets going into two new nuclei

Molar. The posterior permanent teeth usually serving as grinders in a mammal.

Monoecious. Hermaphrodite.

Monohybrid. Offspring of parents that differ in one set of characters.

Morula. The early embryo composed of a solid mass of undifferentiated blastomeres after the cleavage.

Mosaic vision. The fitting together of several partial images into a complete one in the compound eye of an Arthropod.

Moult. To cast off the cuticle, scales, feathers or fur.

Mucous. Secreting mucus or slimy and sticky substances.

Mutation. Discontinuous variation. Abrupt variation that is inherited.

Mutualism. Mutually beneficial interspecific association.

Myotome. A muscle segment.

N

Nacreous layer. The inner mother-of-pearl layer of molluscan shell.

Naris. (Pl. Nares). The opening of the air passage in the head of a vertebrate.

Natural selection. The elimination of the less fit individuals in the struggle for existence as a result of unfavourable environment.

Nauplius. The first larva of many Crustacea.

Nekton. Pelagic animals independent of currents and waves.

Nematocyst. Sting of Coelenterates.

Neoteny. Prolongation of the larval condition as in the axolotal of *Amblystoma*.

Nephridium. Excretory tubule of Annelids, Molluscs and some Arthropods.

Nephrostome. The ciliated funnel-shaped entrance from coelom into the nephridial tube.

Nerve. A bundle of insulated nerve fibres outside the brain and spinal cord.

Neuron. Nerve cell with protoplasmic extensions like axon and dendron that conduct impulses.

Nocturnal. An animal that is active at night and rests during the day.

Notochord. An elastic axial rod-like internal skeletal support ventrad of the nerve cord in the embryo of all chordates. It is surrounded by vertebrae in the vertebrates

Nucleolus. The well defined part of nucleus.

Nucleus. A specialized and usually central part of cytoplasm that controls the metabolism of the cell. Present in all cells except Bacteria.

Nymph. The immature stage of an insect with incomplete metamorphosis.

O

Ocellus. Simple eye of an Arthropod.

Ocular. Pertaining to the eye.

Oesophagus. The part of the alimentary canal between pharynx and stomach.

Olfactory. Pertaining to the sense of smell.

Ommatidium. The visual unit in a compound eye.

Omnivorous. Feeding on all kinds of food.

Ontogeny. Development of the individual.

Oocyte. Egg cell in maturation.

Oogenesis. Development of the oocyte from the primordial germ cell.

Oosperm. Zygote.

Operculum. The fold of skin or plate that covers the gills in bony fishes and in amphibia.

Ophthalmic. Pertaining to the eye.

Opisthocoelous. Vertebra that has the centrum concave behind.

Optic. Referring to the sense of sight.

Oral. Pertaining to the mouth.

Organ. A group of cells or tissues that serve as a separate functional unit.

Organelle. Specialized part of a Protozoan that performs a special function.

Osmosis. Diffusion through a semipermeable membrane.

Osphradium. Chemoreceptor sensory organs of some Mollusca.

Ossicle. A small bone.

Ostium. (Pl. Ostia). Opening into a passage generally guarded by valves.

Otic. Pertaining to the ear.

Otolith. Concretion of calcium salts in the inner ear of vertebrates.

Ovary. The organ that produces the egg cells.

Oviduct. The tube for the passage of the ova.

P

Pallium. The mantle of Mollusca.

Palpus. An appendage of an Arthropod bearing tactile and gustatory sensories.

Parasite. An animal that lives in or on another (host) and at the expense of the latter, giving nothing in return.

Parthenogenesis. Development from an unfertilized ovum.

Pathogenic. Productive of disease.

Pectoral. The region of the body bearing the forelimbs.

Pedogenesis. Sexual reproduction by immature animals.

Pedipalp. Second pair of appendages of Arachnida.

Pelagic. Referring to the open sea.

Pelvic. The region of the body bearing the hindlimbs.

Penis. Copulatory organ of male.

Pentadactyl. Having five digits.

Pepsin. An enzyme of the gastric juice capable of changing proteins into peptones.

Pericardium. The membrane (and also the cavity) enclosing the heart.

Periostracum. The outer horny layer of a Molluscan shell.

Peristalsis. Rhythmic contractions of a hollow muscular organ.

Peritoneum. The serous membrane (of mesodermal origin) that lines the body cavity and covers various organs.

Phagocyte. A white corpuscle that engulfs and destroys foreign material.

Pharynx. The part of the alimentary canal between the buccal cavity and oesophagus.

Phenotype. An animal considered as a complex of visible characters without regard to the genotic constitution.

Phylogeny. The evolutionary history of an animal. Development of the race.

Pia mater. The connective tissue membrane that closely adheres to and covers brain and spinal cord.

Pineal body. Dorsal outgrowth of the diencephalon in vertebrates. It is a vestigial median eye that was functional in ancient extinct primitive vertebrates. It has now an endocrine function.

Pinna. The lobe of the external ear.

Pituitary body. Ventral outgrowth of the diencephalon in vertebrates with which joins a dorsal outgrowth of the roof of the buccal cavity. It has an endocrine function and secretes a hormone called *pituiterin*.

Placenta. The organ by which the embryo of higher mammals is attached to the wall of the uterus of the mother, formed partly of the chorion and partly of uterine wall, and through which diffusible substances pass from the mother to the foetus and vice versa.

Plankton. Small and weak pelagic fauna that move passively at the mercy of currents.

Plantigrade. Walking on the sole of the foot as in bear and man.

Plasma The liquid part of blood.

Plasmosome. A nucleolus not composed of chromatin.

Pleural cavity. The part of coelom in mammals that contains the lungs.

Plexus. A network of nerves.

Polar body. A nonfunctional small cell from the maturation division of an oocyte.

Polyandry. The mating of one female with many males.

Polyembryony. The development of several embryos from one zygote.

Polygamous. The mating of one male with several females.

Polymorphism The existence of more than one form of the same species of animal.

Polyp. An attached Coelenterate.

Population. The total number of species living in any given connected part of the biosphere.

Portal system. A capillary system interposed in the course of a vein.

Posterior. Behind. Away from the head.

Precocial. Birds, the young of which have down and are active when hatched.

Predaceous. Preying on other animals.

Prehensile. Adapted for grasping.

Procoelous. Vertebra with the anterior end of centrum concave.

Proctodeum. The ectoderm-lined terminal part of the alimentary canal.

Proglottid. Segment of a tapeworm.

Pronephros. Primitive kidney of the Vertebrates, functional only in the hagfish.

Pronucleus. The nucleus of a gamete, containing the haploid number of chromosomes.

Prophase. Early period of mitosis up to the aligning of the chromosomes in the equator of the spindle.

Prostomium. A dorsal lobe overhanging the mouth in an Annelid.

Protandrous. Ripening of the testes before the ovaries in a hermaphrodite.

Protoplasm. The complex colloidal physicochemical system that exhibits the properties of life. Physical basis of life.

Proventriculus. A glandular enlargement of the alimentary canal in front of the gizzard.

Proximal. Near the place of attachment in contrast to *distal*.

Pseudopodium. The flowing extensions of the protoplasm in amoeba that serve for locomotion and for ingulfing food.

Pulmonary. Pertaining to lungs.

Pupa. Resting stage between larva and adult insect.

R

Radial symmetry. Similar parts arranged around a common central axis as in hydra or starfish.

Radula. The rasping apparatus, ribbon-shaped and armed with chitinous teeth, of many Mollusca, like snails.

Recapitulation theory. Biogenetic law.

Recent. The present geological epoch.

Receptor. A free nerve ending or a sense organ that receives sensory impulses.

Recessive character. The character from one parent that remains undeveloped in the offspring when associated with the corresponding dominant character from the other parent.

Rectum. The terminal part of the alimentary canal.

Redia. Larval stage of flukes passed in a snail.

Reduction division. The division of the germ cells by which the diploid number of chromosomes is reduced to the haploid during gametogenesis.

Reflex arc. A chain of cells, in the simplest case three neurons involved in a reflex action.

Reflex action. Action that results from the reflection of an afferent sensory nerve impulse as an efferent motor impulse independent of the higher nerve centres.

Regeneration. Regrowth of parts lost through mutilation.

Renal. Pertaining to the kidney.

Reproduction. The production of a new organism by an older one.

Respiration. The exchange of oxygen and carbon dioxide in a living organism.

Retina. The innermost cellular layer of the eye containing light receptors.

Retrogressive metamorphosis. Metamorphosis in the course of which an animal goes backward to a condition characterizing animals lower in scale of organization.

Reversion. The reappearance of an ancestral character that has been in abeyance.

Rostrum. The projecting snout or beak on the head.

Ruminant. Herbivorous mammal like the cow that chews the cud.

S

Sacrum. The part of the vertebral column that articulates with the pelvic girdle.

Sagittal. Pertaining to the median anteroposterior plane in a bilaterally symmetrical animal.

Saprophyte. An organism that feeds on decaying or dead organic matter.

Sarcode. The name given to protoplasm by Du Jardine.

Scansorial. Adapted for climbing.

Schlussverein. Climax community.

Scolex. The attached end of tapeworm.

Scyphistoma. Attached polyp-like stage of Scyphozoa.

Secondary sexual characters. The characters that distinguish the two sexes but do not function directly in reproduction.

Secretion. A useful substance produced by a cell or by a gland. The process of production of such a substance.

Sedentary. Remaining in one place. Animals that lack the power of locomotion.

Sedimentary. Rocks formed by sedimentation in water, that often contain fossils.

Segment. A part that is marked off from the rest.

Segregation. Separation of paired genes during maturation, resulting in the germ transmitting only one gene.

Seminal receptacle. Sac in female for storing sperm received in coitus.

Seminal vesicle. Sac in male for storing sperm prior to coitus.

Septum. Partition between two cavities.

Serum. The plasma of blood that contains no cells or fibrin and that oozes out from a blood clot.

Sessile. Incapable of free locomotion. Sedentary.

Seta. A bristle.

Sex chromosomes. The special chromosomes that determine the sex of an animal.

Sex-linked character. A character, the gene of which is located in the sex chromosome.

Sinistral. Referring to a gastropod molluscan shell spirally coiled to the left.

Sinus. An enlarged blood space. A cavity in a bone.

Skeleton. The hard frame-work of the body.

Solitary. An animal that lives alone and not in colonies.

Species. A distinct kind of animal.

Sperm. Spermatozoa. The mature male reproductive cells.

Sphincter. Muscle that surrounds an opening, which it closes by contraction.

Spicule. Minute crystal-like calcareous or siliceous particles embedded in the tissues of an animal and serving to stiffen the part.

Spindle. Part of cell during mitosis that lies between the centrosome and having the appearance of fibres.

Spiracle. The external opening of the tracheal system of insects. The modified first gill-slit of a cartilagenous fish.

Spireme. Thread of chromatin in the early prophase, breaking subsequently into chromosomes.

Spontaneous generation. Abiogenesis.

Spore. A reproductive cell enclosed in a resistant covering.

Sporocyst. A sac-like larva of fluke in a snail.

Statocyst. Organ of equilibrium and orientation.

Stimulus. An environmental change capable of influencing the activity of an animal.

Stomodaeum. The ectoderm-lined anterior part of the digestive tract.

Stratified. Arranged in layers.

Strobila. Individuals produced by longitudinal budding as in Scyphozoa or Cestoda.

Strobilation. Longitudinal budding.

Succession. The successive occupation of a given area by different types of animals.

Superficial cleavage. Segmentation leading to a layer of blastomeres surrounding a central yolk.

Symbiosis. The mutually beneficial interspecific association of animals.

Symphysis. The union of two parts.

Synapse. The contact of one nerve cell with another.

Syncytium. A layer of protoplasm containing many nuclei not separated by cell walls.

Syrinx. The vocal organ in bird.

Systemic. The part of the blood vascular system that is not directly involved in respiration.

T

Tactile. The sense of touch.

Telencephalon. Anterior region of brain comprising the olfactory lobes and cerebral hemispheres in vertebrates.

Telolecithal. Ovum with yolk concentrated at one pole.

Telophase The late phase in mitosis in which the protoplasm is divided and nucleus reforms.

Tendon. The connective tissue that attaches muscle.

Tentacle. Flexible appendage usually surrounding the mouth.

Testis. (Pl. Testes) The male gonad.

Tetrapod. A vertebrate with four limbs.

Thorax. The part of the body behind the head.

Tissue. A group of cells with the same structure and function.

Tornaria. A ciliated larva of Balanoglossus.

Trachea. Air tube of insects. The wind pipe of terrestrial vertebrates.

Trichocyst Stinging apparatus of Paramecium.

Triploblastic. Derived from three germinal-layers ectoderm, endoderm and mesoderm.

Trochophore A pear-shaped larva, with an equatorial band of cilia, found in Annelida and Mollusca.

Tropism. The tendency of an animal to turn to or away from a stimulus.

Trypsin. A pancreatic enzyme capable of changing proteins into amino acids.

Tympanum. Eardrum.

Typhlosole. A longitudinal fold of the wall projecting into the cavity of intestine as in the earthworm.

U

Umbilical cord. The cord that connects the foetus with the mother and that contains blood vessels.

Umbo. The oldest part of the shell of a bivalve Mollusc.

Ungulate. Hoofed animal like the cow or horse.

Unguligrade. Walking on hoofs.

Ureter. The duct that carries the urine from the kidney to the urinary bladder.

Urethra. The duct that carries the urine from the bladder to the outside.

Uterus. The enlarged posterior part of the oviduct in which the eggs undergo development.

V

Vacuole. A liquid filled space in protoplasm.

Vagina The terminal part of the reproductive tract in a female for the reception of the copulatory organ of the male.

Vas deferens. The duct from the testis to the outside.

Vas efferens. The tubule between vas deferens and testis.

Vein. A vessel that carries the blood toward the heart.

Veliger. A ciliated larva of Mollusca.

Ventral. The lower side in contrast to the dorsal.

Ventricle. A chamber of the heart or of the brain.

Vermiform appendix. The vestigial caecum in primates.

Vertebra. The segmental skeletal unit of the backbone.

Vestigial. A degenerate organ that was formerly fully functional.
Viscera. The organs within the thorax and abdomen.
Visceral skeleton. The frame-work of the jaws and gills in vertebrates.
Vitamin. Accessory food factor that is essential for natural function.
Volant. Capable of flying.

X

X-chromosome. Paired or unpaired sex determining chromosome.

Y

Y-chromosome. Unpaired sex determining chromosome.
Yolk. Nutritive reserve in egg.

Z

Zooid. Asexually produced individual in a colony.
Zygote. The fertilized ovum.

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INDEX

Synonyms are printed in *italics*. Italicized numbers indicate pages with figures.

A

D

G

I

M

Q

R

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